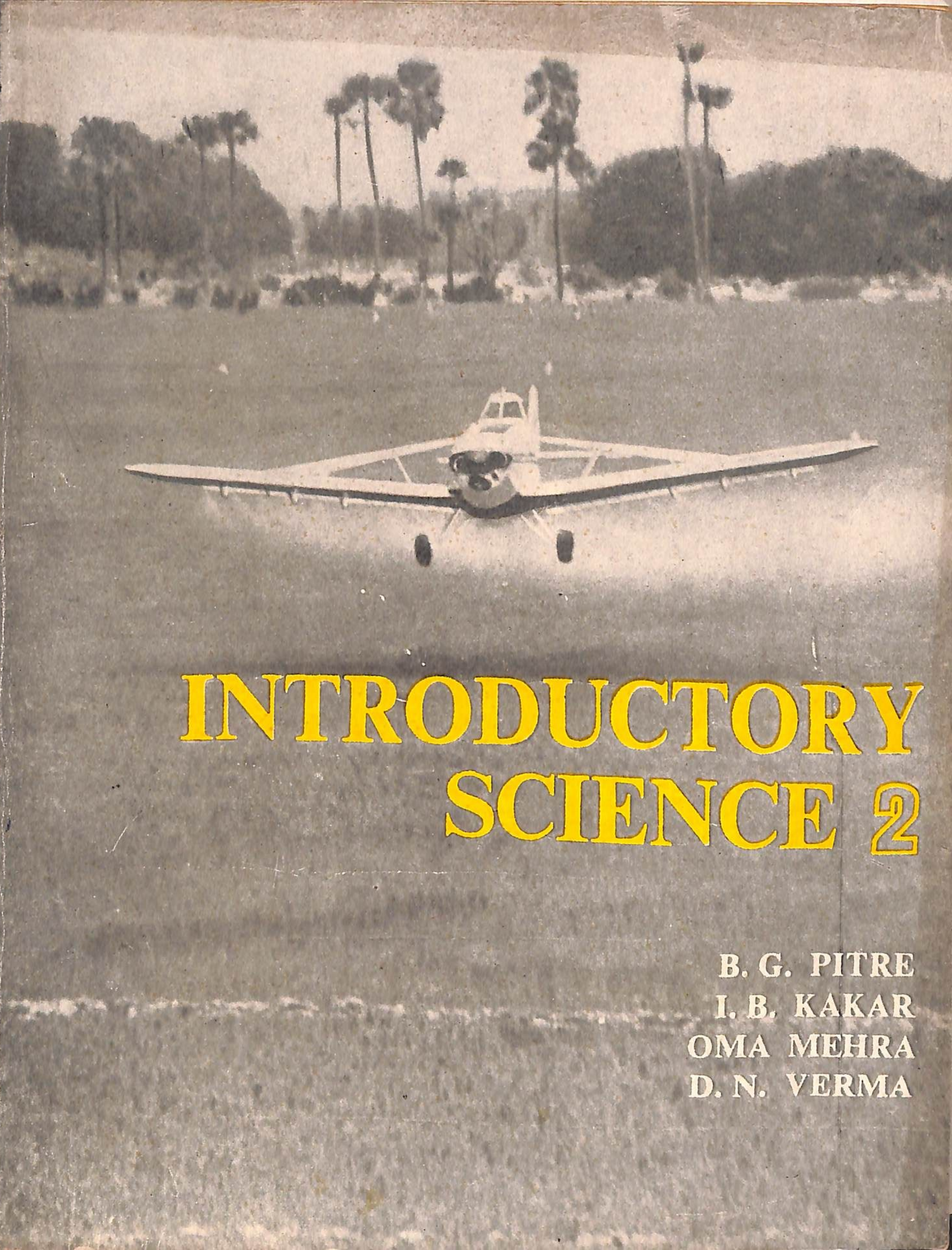

INTRODUCTORY SCIENCE 2

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INTRODUCTORY SCIENCE 2
A Modern Approach

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Contents

To the Teacher

In the past decade we have witnessed a number of attempts to revise curriculum and rewrite science texts for the Junior High School classes. Opinion among science educators all over the world seems to oscillate between two extreme positions—an integrated, thematic approach which most teachers find insufficiently equipped to teach, and a separate disciplined approach which is in vogue at present in our country.

It has been the cherished dream of all science educators to conceive a unified science curriculum which enables students to appreciate science as a human endeavour influencing our society, culture and daily life, and to implement it in an integrated fashion providing glimpses of skills, techniques and concepts which form the very core of all scientific activity. Several attempts have been directed to develop new materials on the assumption that the syllabus prescribed by various educational Boards will fall in line, and that the introduction of these texts and kits in schools would significantly improve the teaching of science.

One does not need a second opinion to be convinced that the availability of new materials has had little qualitative impact on actual classroom teaching. Many reasons have been given for this state of affairs. Nevertheless, it can be safely assumed that besides a syllabus and the examination system, the texts and the teachers who use them in their classes form the vital links between a dream and its realisation.

The authors have written these texts based on their wide and deep experience in teaching and working in collaboration on several approaches to science teaching. These texts in three volumes cover approximately the three-year course in science at the middle school stage in English medium schools. The authors hope that the texts will commend themselves in providing sufficient knowledge for an intelligent appreciation of the modern progress in science, while creating a broad unified background and a strong foundation to serve as a preparatory course for the three specialised disciplines at the secondary stage.

In offering these texts to the pupils, the following considerations have weighed upon our minds:

(*a*) Theory should be sufficiently interspersed with practical activity in the development of a topic. Many experiments and demonstrations have therefore been suggested so that students may be guided to conclude and form concepts based on the observation and interpretation of the experiments.

(*b*) Lengthy explanations, unnecessary mathematical derivations and irrelevant taxonomical details should be avoided in a first-acquaintance presentation to science. Problems, both theoretical and numerical, have therefore been included with an aim to show further applications of the principles rather than to engage pupils in repetitive work.

(*c*) Next to a first hand experience of apparatus and phenomena, clear illustrative diagrams and photographs are the best aids to a proper assimilation of the subject, and of its extension to technology and environment in the out-of-school world. No time and effort has been spared to equip the text with illustrations.

Concept development in students is a gradual, cumulative process; the sequence of topics should therefore be psychological rather than logical. The unconventional presentation of course content in these texts enables a lot of good science to be taught in an economical and efficient way. It has been successfully trial-tested for several years by the authors and their colleagues, yet it gives the teacher a relatively free choice to select his own sequence.

The authors realise that there is no unique way to teach a subject. Moreover, a first attempt to present it in a book form lacks refinement. It would therefore be appreciated if they receive critical comments and suggestions from teachers who actually use the texts in their classrooms.

September 24, 1975

B.G. PITRE
General Editor

1 Measurements

A cricket bowler walks away from the pitch, counting paces as he does so, and makes a visible mark on the ground where he stops. He then turns round, ready for a run, and takes one or two practice runs till he gets proper foot on the pitch. Why does he count paces? Why does he, while counting paces, walk with a slow and and regular rhythm? Have you heard umpires calling a 'no ball' when a bowler's foot is faulty on the crease as he releases the ball?

LENGTH

Take an event on the athletic field. A broad jump athlete walks slowly away from the jumping board and stops at his measured mark. In any measurement he ensures that the measure ***one pace*** covers the same distance each time; that each pace does not stretch nor contracts. If the distance of his run is ***20 paces***, it means that the distance is 20 times the length of his pace. ***A pace is his personal unit of length.***

Measurement is a process in which an unknown quantity is compared with some chosen quantity of the same kind. Any measurement always contains two terms: a number and a unit, and is a product of the two.

Does another athlete also use the same mark for the start of his own run? Two athletes may both count the same number of paces and yet cover different distances. This is because both use their own pace as a measure of distance. It may serve their own purpose but not necessarily someone else's.

When the jumps are taken, a field judge does not measure the distance covered by a jump by his own pace bacause he cannot be sure of the uniformity of his steps each time. If such distances can be compared by using a tight string, one can tell who has come first in a particular event. Using a string, however, a judge cannot tell whether the athlete has established a new record. For this purpose the jumps of all years have to be compared. Distances are therefore "measured" in multiples of a ***standard*** unit : a ***metre*** or a ***cm.***

A standard unit is so chosen that any measurement expressed in the unit can be communicated or stored without confusion or vagueness. Furthermore, the standard should be easily reproducible and its property for which it is used should not change.

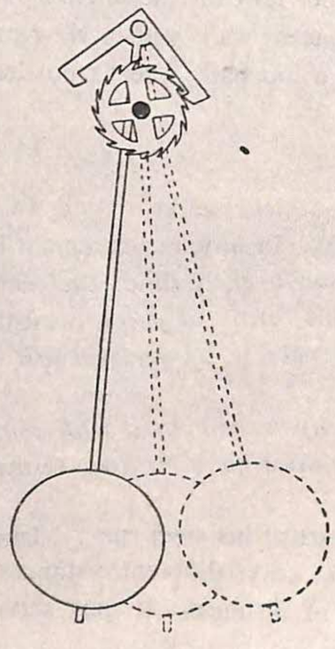
During an athletic meet measurements of all kinds are being made. Field judges

are measuring distances using tapes, and track judges are timing athletes with stop watches. Athletes are being weighed in for grading in different events. Whether on playing fields or in classrooms, in research laboratories or in factories, measurement is an activity we undertake many times a day. A scientist, Lord Kelvin, once said : "Unless you can measure what you are speaking about, and express it in numbers, you have scarcely advanced to the stage of science."

TIME

Unlike the units of length, the unit of time cannot be stored; it must therefore repeat itself. A system which repeats itself at regular intervals of time is called a ***periodic system.*** The measurement of time is really the comparison of an unknown time interval with a standard time interval of a periodic system.

One of the ***natural*** periodic phenomena known to man from early times is the repetition of day and night due to the spin of the earth round itself as it revolves round the sun. As the earth's orbit around the sun is not quite circular, a solar day varies slightly in duration over the year.



(a) Pendulum mechanism in a clock

(b) Balance wheel in a watch

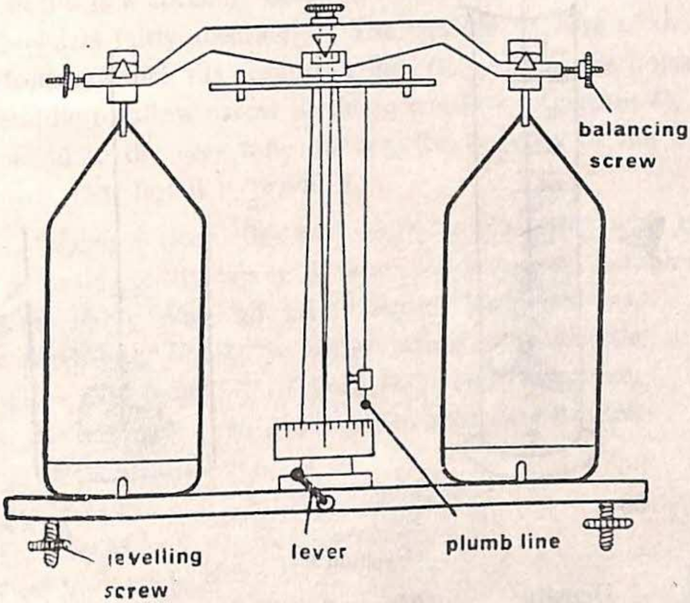
Diagram 1

Sun dial, water and sand clocks were used in earlier ages for measurement of time intervals. These were inconvenient to use because, whereas the sun dial could not be moved from place to place, the water and sand clocks had to be attended to regularly. The real advancement was made when clocks were invented. A clock has a pendulum which ***oscillates*** at regular intervals of time (diagram 1*a*). The balance wheel of a watch (diagram 1*b*) has the same function.

MASS

Mass is measured in comparison with other ***standard*** masses. A standard unit of mass is a kilogram (kg). If a kilogram mass is placed in one pan of a beam

balance which has equal arms and any other material is placed in the other pan so that the beam is horizontal, then each is equally being pulled by the gravity of the earth. Hence, the two have equal mass. Thus, a beam balance is used to measure mass by comparison with other standard mass.



A physical balance
Diagram 2

VOLUME

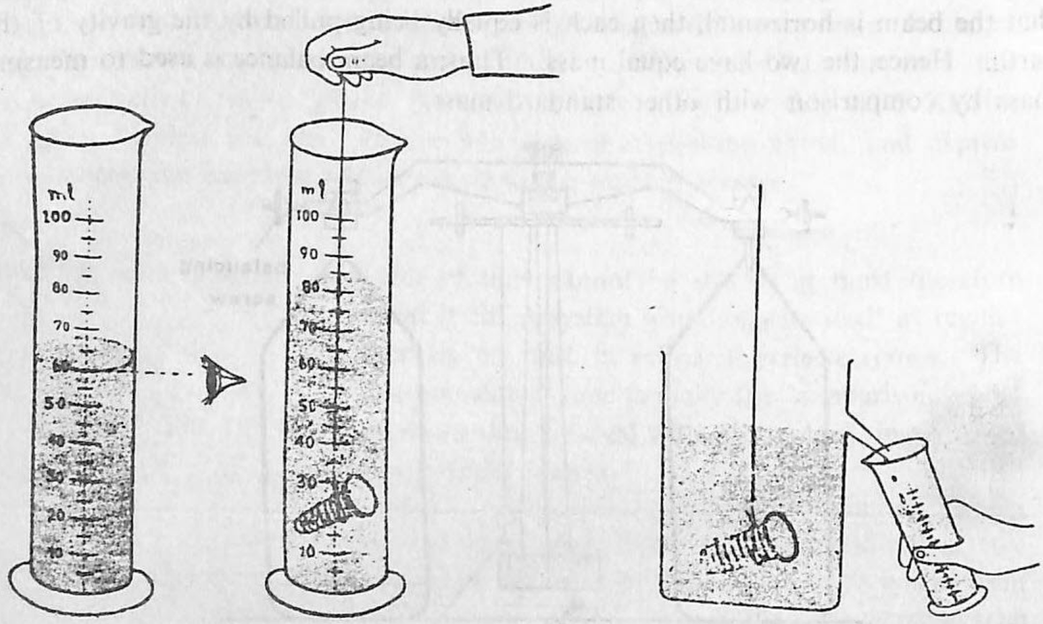
Another important property of matter is its ***volume***, the space that any object occupies. A shadow, an idea, or vacuum are not matter because neither do they occupy space, nor have they any mass. Whether an object is a solid, liquid or gas, it has some volume.

A solid has more or less a fixed shape; it is not easy to change this shape. Some solids have a regular shape; in such cases, their volume can be easily found out by physical measurements. For example, a rectangular block, a cone, a sphere are regular solids. The volume of a rectangular block is the product of its length, breadth and thickness.

The volume of an irregular solid object is found out by the method of displacement. A liquid, say water, poured in a measuring jar or an overflow can will be displaced by a solid put in it (diagram 3). The volume of displaeed water equals the volume of the solid.

DENSITY

The mass of a unit volume of a material is called its density. For any one material, the ratio of mass/volume, which gives the mass of one cm^3, is constant.



(a)

(b)

Diagram 3

$$\text{Density } (g/cm^3) = \frac{\text{Mass of an object (g)}}{\text{Volume of the object } (cm^3)}$$

Equal volume of different materials have different masses; hence, they have different densities.

RELATIVE DENSITY

The density of iron is about 8 g/cm^3 while that of aluminium is 2.7 g/cm^3. How many times is iron ***denser*** than aluminium? ***Relative density*** is the ratio of density of one material to the density of another material. For example, the relative density of iron is 3 in comparison to aluminium. Such an information is helpful in deciding which material should be used in a particular technology, such as construction of aircraft, girders for bridges, etc.

It is customary, however, to mention relative densities in relation to water as the standard material. Taking the case of iron, its relative density (*R.D.*) with that of water would be 8. The R.D. of mercury is 13.5.

Expressed mathematically,

$$\text{Relative Density of a material} = \frac{\text{Density of the material}}{\text{Density of water}}$$

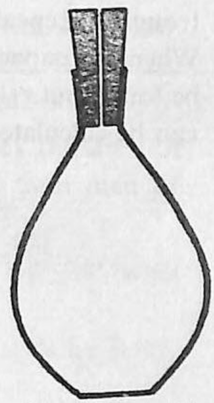
It is important to note that the density of a material in different units will have

different numerical values; however, the R.D., as a ratio of two densities expressed in the same units, will have no units.

THE DENSITY BOTTLE

The density bottle is a specially designed bottle that allows us to find the R.D. of liquids and powders fairly accurately. The essential feature of the bottle is that it has a glass stopper, which fits accurately into the neck of the bottle, and has a hole through its middle to allow excess liquid to overflow (diagram 4). This allows the bottle to be filled to the very top. Hence, the capacity of the bottle remains the same no matter what liquid is inside it.

Activity 1. Weigh a clean, dry and empty bottle along with the stopper. Fill it fully with a liquid, gently tap it to drive away any air bubbles, and push the stopper into the neck. Wipe off excess liquid that overflows, and re-weigh the bottle. Similarly, weigh water in the bottle taking care that the bottle is cleaned and dried properly before water is poured. The observations can be recorded systematically as follows :



The density bottle
Diagram 4

Mass of empty bottle	$= x$ grams (say)
Mass of bottle + liquid	$= y$ grams (say)
Hence, mass of liquid which fills the bottle	$= (y-x)$ grams
Mass of bottle + water	$= z$ grams (say)
Hence, mass of water which fills the bottle	$= (z-x)$ grams
Hence, R.D. of liquid	$= \dfrac{\text{Mass of liquid}}{\text{Mass of equal volume of water}}$
	$= \dfrac{y-x}{z-x}$

DENSITY OF AIR

A difficulty about finding the density of gases is that they weigh very little, so that we are required to take a large amount of gas to weigh them on ordinary balances. There is also another real difficulty.

Activity 2. Take a bicycle pump and put your thumb over the hole so that no air can come out when you push the piston down. Push the piston down and then release it. What do you notice? Squeeze a hollow rubber ball and then leave it. Does it remain squashed ? Pump a lot of air into a bicycle tube and see how the tyre holds the air you squeeze into it.

From these simple experiments on air you will realise that a gas can be compressed

rather easily like a spring. This poses a problem of finding out its density. The density would be quite different for air if it is squashed (like air in bicycle tube) than for the air you breathe. Would the air inside the bicycle tube have a greater or lesser density than the air outside?

Activity 3. Take a large polythene or tin container, like those used for storing petrol or oil, and attach a tap to it. Weigh the container on a large beam balance. Now pump a lot of air into the container again; its mass should increase by about 6 grams. This increase in mass gives the amount of air pumped into the container from outside.

Now release the compressed air under water in a trough so that bubbles of air rise and are displaced in a jar which was initially full of water (diagram 5). When all the water is displaced, take the jar out, fill it with water again and place over the trough. Repeat the process till you get as many jars filled with air as you can. When the capacity of one jar is known, the total volume of air which came out can be found out. The mass of this air has already been determined. Hence, its density can be calculated.

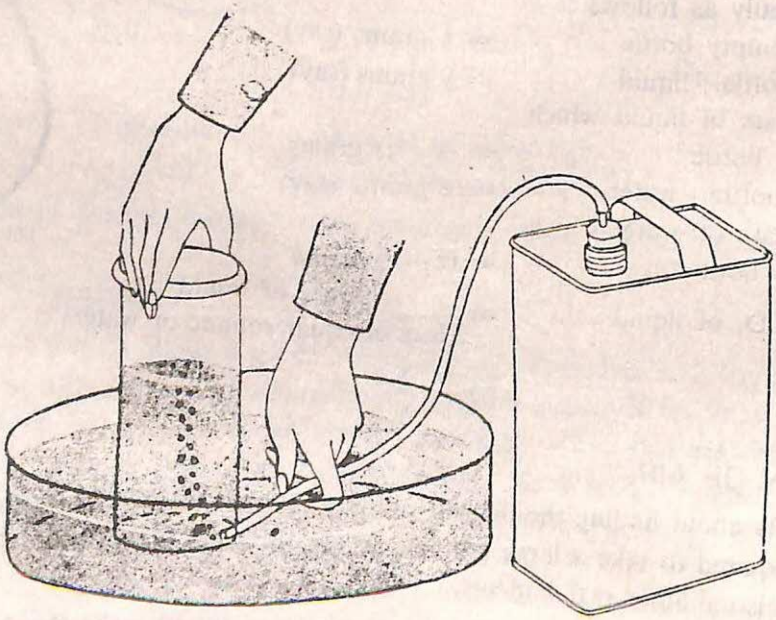


Diagram 5

DENSENESS OF MATTER

If you look at a list of materials and their densities, you will realise that solids generally have a density greater than liquids, and gases are materials of least density. Can you give any reasons for this?

It is common experience that you can easily walk through air, but not so easily through water and not at all through a solid wall. It appears that the particles in solids are closer together than in liquids and gases, that there are fewer particles in 1 cm^3 of air than in an equal volume of water or aluminium.

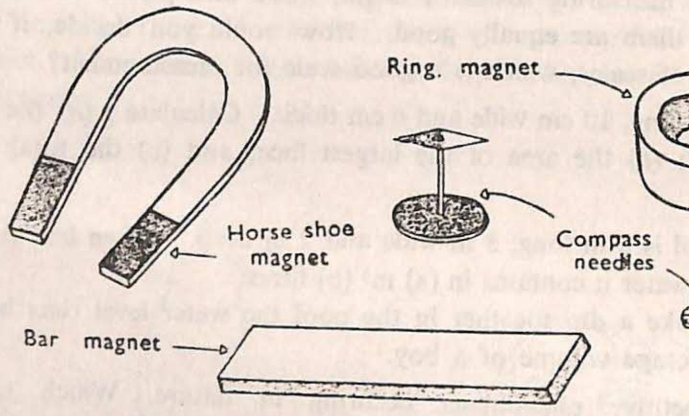
Why is a unit cube of aluminium less dense than a unit cube of iron? Is aluminium loosely packed, or has a particle of aluminium less mass than a particle of iron? We shall investigate these points at some later stage.

PROBLEMS

1. In everyday use, measuring scales of metal, wood and plastic are employed. Discuss if all of them are equally good. How would you decide, if you are given the choice of scales, which is a good scale for measurement?
2. A brick is 25 cm long, 10 cm wide and 6 cm thick. Calculate : (*a*) the area of the smallest face; (*b*) the area of the largest face; and (*c*) the total area of all its faces.
3. A swimming pool is 8 m long, 5 m wide and 2 m deep. When half full, what is the volume of water it contains in (a) m^3 (b) litres.
   When 20 boys take a dip together in the pool the water level rises by 9 cm. Calculate the average volume of a boy.
4. Name two repetitive phenomena occuring in nature. Which repetitive phenomena exist in the human body?
   What is the difference between a repetitive and a periodic phenomena?
5. An empty density bottle weighs 20.2 g-f and when filled with water it weighs 45.2 g-f. It weighs 40.2 g when filled with kerosene oil.
   Find (*a*) the capacity of the bottle; (*b*) the density of kerosene oil; (*c*) the mass of 1 cm^3 of kerosene oil.
6. An iron girder is 5 m long, 25 cm wide and 20 cm thick. Find its mass, taking the density of iron to be 7.8 g/cm^3.
7. A window pane is 1 metre square and 3 mm thick. Find its mass, if density of glass is 2.5 g/cm^3.

2 Experiments with Magnets

Magnets are available in various shapes and sizes. At some time or the other you must have played with a magnet and marvelled at its property of attracting nails and pins. Do magnets only pull and never push? Do magnets attract any other objects besides nails, pins, etc.?



Various types of magnets in use
Diagram 6

MAGNETIC MATERIALS

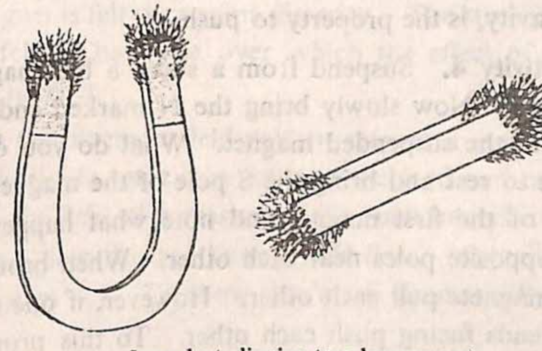
Activity 1. Collect a number of small objects such as paper clip, brass screw, copper wire, iron nail, sewing needle, piece of wood, candle, glass rod, brass, split pin, plastic scale, glass lens, steel spring, plastic knitting needle, post card. Test them with a magnet. List them under the headings: affected by a magnet, and not affected by a magnet.

Our experiment shows that only objects made of iron and steel are pulled by a magnet. As a matter of fact, objects made of iron, cobalt and nickel can only be strongly attracted by a magnet. These materials are called ferro-magnetic or simply ***magnetic materials.*** Scientists have now developed several other materials which are strongly magnetic; among these are alloys of iron, nickel and cobalt, ceramic materials like ferrites, and some special plastics. Materials which are not affected by a magnet, such as wood, glass, copper, etc. are called non-magnetic materials.

POLES OF A BAR MAGNET

Is the force of attraction in a magnet distributed all over it?

Activity 2. Take some iron dust and sprinkle it on a bar magnet. Do you notice how the dust clings to the magnet? Now take an iron nail and touch it along the length of the bar magnet at several places. Is there a place where the attraction is greater than others?

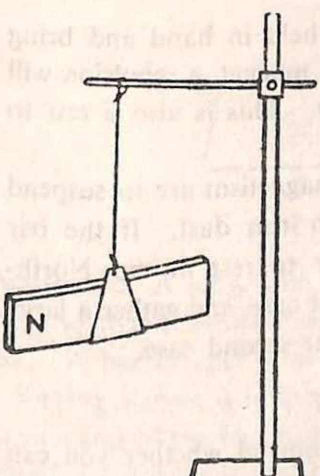


Iron dust clinging to a bar magnet
Diagram 7

You would find that iron dust makes a little bunch at each end of the magnet. The attraction on the nail is also greatest at the ends of the magnet. The regions near the ends where the attraction is greatest are called the poles of the magnet; a bar magnet has two poles.

DIRECTIONAL PROPERTY

Activity 3. Suspend a bar magnet from a wooden stand (why wooden?) by using a paper hung from a thin thread. Make sure that there are no magnets or heavy iron masses nearby. After a few ***oscillations*** the magnet will come to rest. Disturb it from its position of rest and see what happens. Move the stand to some other position in the room and repeat the experiment.



A suspended bar magnet
Diagram 8

You will notice that the magnet always comes to rest in the same direction; this direction is approximately along the geographic north-south. Mark the end pointing north as N; we call this a ***north-seeking pole.*** Mark the other end as S; this is called a ***south-seeking pole.***

There are two other simple ways of allowing a magnet to set itself freely in any direction. Some magnets are pivoted on a sharp point. Another method is to float a magnet on a cork in a trough of water; be sure that the magnet is perfectly still. The magnet will swing round and come to rest in approximately north-south direction. It should be noted that the cork does not move either to the north or to the south but stays where it is in water.

ATTRACTION AND REPULSION

One of the striking differences between the pulls of the earth and the magnet is that while a magnet seems to attract only those objects made of magnetic materials, the gravity of the earth pulls all objects around it. The two attractions are of entirely different type. However, a second interesting fact about magnets, absent in the case of gravity, is the property to push.

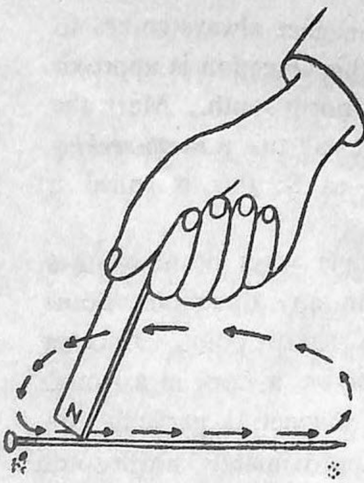
Activity 4. Suspend from a stand a bar magnet whose poles have already been marked. Now slowly bring the N marked end of another magnet closer to the N pole of the suspended magnet. What do you observe? Let the suspended magnet come to rest and bring the S pole of the magnet in hand closer to the south-seeking pole of the first magnet and note what happens. Do the same thing by bringing the opposite poles near each other. When brought closer in one way, we find that the magnets pull each other. However, if one of the magnets is turned round, the two ends facing push each other. To this property of push we give a new word: ***repulsion.*** The conclusions from this experiment could be written as follows :

Like poles repel and unlike poles attract each other.

TEST FOR MAGNETISM

A magnetic pole attracts an un-magnetised piece of iron as well as the opposite pole of another magnet. From this experiment alone, it is not possible to state definitely whether the other object is magnetised or not.

To test for magnetism, reverse the end of the magnet held in hand and bring it closer to the two objects. If any of the other objects is a magnet, a repulsion will be observed. Thus, *repulsion is a sure test for magnetism.* This is also a test to know whether the bar held in hand is a magnet or not.



Stroking method
Diagram 9

Other methods to test magnetism are to suspend the bar freely, or dip it in iron dust. If the bar is a magnet, it will come to rest in the North-South direction in the first case, and gather a large quantity of iron dust in the second case.

MAKING OF MAGNET

You must have often wondered whether you can make a magnet yourself. Here is a simple method using a bar magnet.

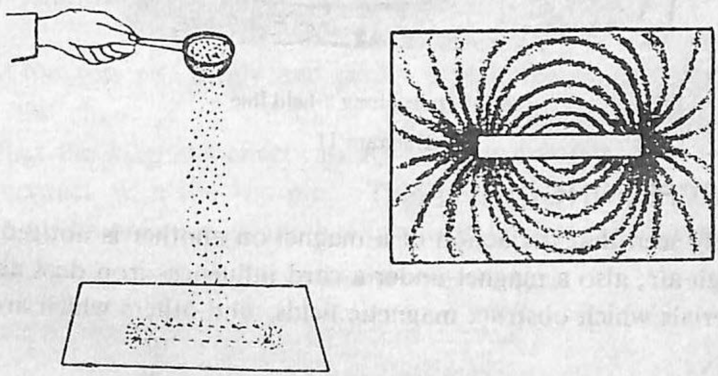
Activity 5. Take a magnetic object such as an iron nail or a paper pin. Stroke it with one end of the bar magnet. Begin stroking the object from one end and when you come to the opposite end,

lift the magnet well away and bring it back to the first end of the object (diagram 9). After doing this for some time, test the object to see if it has become a magnet. How will you find out which end is a north-seeking pole?

MAGNETIC FIELDS

You have noticed that the effect of a magnet is felt over some distance. The stronger the magnet, further away is the effect felt. The space over which the effect of a magnet is felt is known as the ***field*** of a magnet.

Activity 6. A simple way to find out the magnetic field pattern around a magnet is to place a card over a bar magnet. Sprinkle some iron dust on the card and tap the card gently. Did you expect to see the field of a magnet make such interesting pattern? The lines along which the iron dust lies are known ***field lines.*** Actually these are lines along which magnetic forces act. To show this more dramatically, another experiment can be performed.



Field pattern of a bar magnet
Diagram 10

Activity 7. A long, thin magnet made from a knitting needle is passed through a cork so that it floats vertically on water in a trough with one pole just outside water. A bar magnet is now held firmly on the water surface so that the pole of the floating magnet is in level with the bar magnet. Now bring this floating needle near one end of the bar magnet so that two similar poles are close together. When released, the free pole will be pushed away and goes towards the other end of the bar magnet. In doing so, it follows a circular path showing how the magnetic force in the field is acting.

These experiments do not show very well how far the magnetic field extends. One method to find this out is to keep the magnet on a table and gradually bring closer a small compass needle. When the needle is very far off, it points in the north-south direction. When it is brought closer, the farthest distance from the magnet

that it shows a change of direction is the effective range of the field. It may be noted that the field may extend to a much greater distance than shown by the compass, and a more sensitive compass may show a larger field.

A free pole along a field line

Diagram 11

MAGNETIC SCREENING

We have already seen that the action of a magnet on another is noticed even from a distance through air; also a magnet under a card influences iron dust above it. Are there any materials which obstruct magnetic fields, and others which are transparent to this field?

Activity 8. Keep a glass plate over a magnet and sprinkle iron dust on it. Move the magnet from underneath and observe if it influences the iron dust. Report the experiment with a wooden and a plastic scale. Put some pins in water; bring a magnet close to the pins from outside and see if the pins are attracted. One rather difficult set up is to hold a magnet and a compass on either side of an iron sheet without them touching the sheet.

You will notice that the iron sheet, which is a magnetic material, is the only object which does not allow magnetic field to pass through it; all other non-mangetic materials allow magnetic field to pass through them. This property of stopping magnetic field by an iron sheet is used in ***magnetic screening*** or ***shielding***, when we want certain instruments to remain unaffected by outside influences.

MAGNETIC INDUCTION

A very interesting fact about magnets is their property to induce magnetism in magnetic materials which lie around in its field.

Activity 9. Support with a stand a bar magnet veritcally with its N pole downwards. Bring in contact with this pole two paper pins, separated by a small distance from each other (diagram 12). You notice that the two lower ends of the pins do not pull together but separate out. Now bring gradually closer the N pole of another magnet under the pins; the separation is seen to increase.

The experiment suggests that the two pins have become magnets with their lower ends as N poles.

Now remove one of the two pins and hang it from the lower end of the second pin. Try to hang a third pin, and so on, to build up a chain of pins (diagram 13 *a*). See how many pins can be supported in this fashion. Repeat with another magnet. A stronger magnet will support more pins.

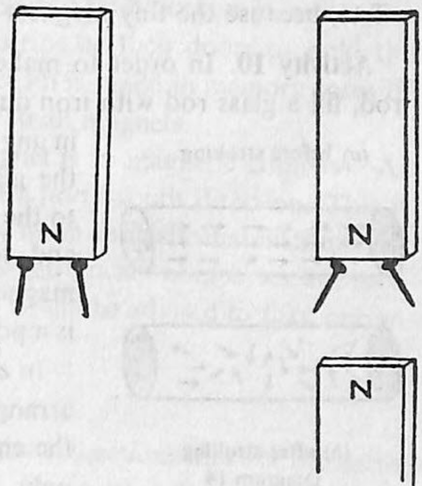
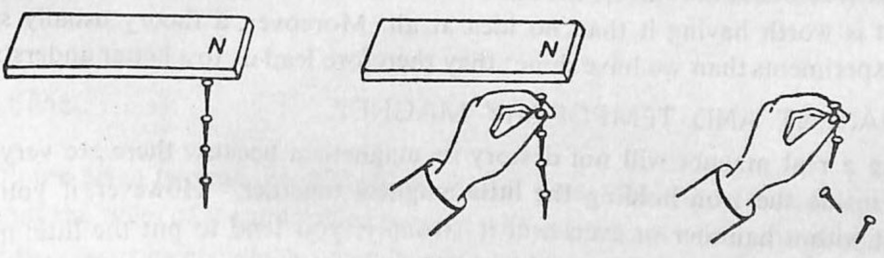


Diagram 12

Now hold the top pin firmly and gently detach the magnet slightly. You will notice that the chain of pins remains together (diagram 13 *b*). It can also be concluded that the magnetic effect can act from a distance, even when the magnet is not in contact with the top pin. This property of creating magnetism in a matreial due to the presence of another magnetic field is called ***magnetic induction.***



Magnetic induction

Diagram 13

If the magnet is gradually moved away, it is observed that the pins begin to fall away (diagram 13 *c*). The experiment shows that the pins have become magnets themselves, but the effect is largely due to the presence of the permanent magnet.

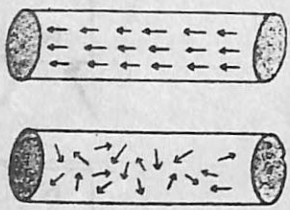
A SIMPLE THEORY OF MAGNETISM

Have you thought how a piece of iron can become a magnet when stroked with a bar magnet? Why is the magnetic force concentrated at the two poles? Some of the earlier experiments may have given you ideas. Suppose you imagine an iron

rod made up of tiny little magnets which were arranged in no particular way inside the rod. In such a situation it is unlikely that the rod would show any magnetic effect, because the tiny magnets would tend to cancel each other's effect.

Activity 10. In order to make a model of what may be happening inside an iron rod, fill a glass rod with iron dust and close both ends. The iron dust is not arranged in any particular way. Now take a bar manget and stroke the glass rod with its N pole and observe what happens to the iron dust (diagram 14). Do this a number of times and test using a compass whether you have made a magnet; if the needle is repelled by one end, then that end is a pole similar to that of the compass which was repelled.

(*a*) before stroking



(*b*) after stroking
Diagram 14

In a similar way the tiny magnets in an iron rod would arrange themselves in the direction of the stroking. Now the ends of the rod have a collection of one type of pole only. This explains the concentration of force at the ends of the magnets. In the middle, the S pole of one magnet is adjacent to the N pole of the next and their combined effect outside is almost negligible. Also notice that the end where the stroking magnet leaves the rod becomes the opposite pole to that being stroked. Can you now think of destroying the magnetism?

This idea (theory) that magnetic materials are made up of tiny magnets is not altogether true but is not far off the mark either. Even if a model explains simple things only, it is worth having it than no idea at all. Moreover, a theory usually suggests more experiments than we have done; they therefore lead us to a better understanding.

PERMANENT AND TEMPORARY MAGNET

Shaking a real magnet will not destory its magnetism because there are very strong forces inside the iron holding the little magnets together. However, if you beat a magnet with a hammer or even heat it strongly, you tend to put the little magnets out of alignment again. Try it with the magnet you have made. (You can always make the object into a magnet again!)

However, in soft iron the little magnets are not so tightly held as in steel. It is therefore easier to magnetise a piece of soft iron than a piece of steel, and it is also easier to de-magnetise soft iron by rough treatment. Since bar magnets in use are supposed to retain their magnetism permanently, they are made of steel. In other cases, where the magnetism is required only temporarily, such as in an electric bell, the material used is soft iron. It may however be noted that all magnetic materials retain some magnetism if they are exposed to a magnetic field even for a short duration; this is known as ***residual magnetism***. In general, the harder iron becomes a magnet with greater difficulty; and once magnetised, remains a magnet longer,

USE OF MAGNETS

In the ordinary household today there are several places where you would find magnets being used. Electric razors, electrically operated toys and loudspeakers in radios use permanent magnets. Refrigerators have magnetic strips on their doors to hold the door shut. One of the most important use of magnetism is made in memory cores of computers. This unit contains many thousands of small magnets.

Of course, a very old and ancient use of the magnet is in magnetic compass. As you know a magnet when suspended aligns itself in a north-south direction. This is very useful in finding direction of travel, and in spite of more sophisticated instruments, aircraft and ships still use the magnetic compass. Small pocket compasses are used by scouts and if you ever go on a hike or a trek, you would be advised to take one so that you do not lose your way.

EARTH'S MAGNETISM

That freely suspended or pivoted magnets point in definite directions all over the earth suggests that the earth has a magnetic field around it. The earth behaves as if a huge bar magnet was embedded deep inside the earth with its poles approximately in the same direction as the geographical poles. However, the earth's field is affected by magentic storms that are due to sudden eruptions in the sun. Some scientists believe that the field is rather complicated and there is no bar magnet as such inside the earth. But that it resembles the field of a bar magnet and lies in a north-south direction is indeed fortunate as centuries of navigators will no doubt vouch for.

PROBLEMS

1. If you are given two magnets of which one has poles labelled on it, how could you find out the poles of the unlabelled magnet without the aid of any other material? Give two experiments which you will perform using any other material you may need, to tell which one of the two is a stronger magnet.

2. You are given three rods which appear exactly alike: one is a magnet, another is of iron and the third of a non-magnetic material. How could you find out which is which?

3. You are provided with a long nail. With the help of any other material you may need, briefly describe two experiments which tell you whether the nail is magnetised and, if so, which end is the S pole?

4. How would you use a bar magnet to magnetise a steel knitting needle so that its

sharp end acquires a north-seeking polarity? Draw a suitable diagram to answer the problem.

5. What is meant by the terms (a) magnetic pole, (b) magnetic field and (c) magnetic induction?

6. Sketch some lines around a bar magnet to show the nature of the magnetic field around it.

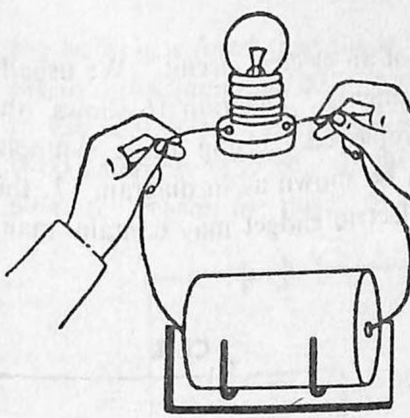
7. How does a simple theory of magnetism explain the facts that (*a*) a magnet has two poles at the ends; (*b*) if a magnet is broken into two halves, then poles appear at the freshly broken ends; (*c*) the magnetism of a bar magnet can be lost if it is heated and hammered?

3 Electrical Circuits

Fans, radios, heaters and irons are some of the electrical appliances which are in common use nowadays. From a handy torch to a giant ice factory, we have become increasingly dependent on the use of electricity for our daily activities. When you switch on an electric light in your home, do you ever wonder how the lamp is made to give light? What about the torch we often use? What part does a cell play in producing the bright beam of light in a torch?

A bus, motor car or a tractor have lamps inside and outside to allow them to be driven at night. If you look under the "bonnet" you will see lots of different coloured wires leading to the headlamps and other electrical gadgets in the vehicle such as the horn, windscreen wiper, and so on. To get an idea of how and why these gadgets work we begin by studying simple electrical circuits containing wires, cells and bulbs.

Activity 1. Take a bulb and connect it to a cell with two wires so that the bulb glows. Inter-change connections of the cell; does it make any difference to the brightness of the bulb? Now turn the bulb round so that its connections are reversed. You will find that there is no difference in the glow.



A simple electric circuit
Diagram 15

The bulb connected by wires to a cell (diagram 15) is a simple electric circuit. When they are connected correctly so that the bulb glows, it is said to be a ***complete circuit***. You must have seen that both ends, called ***terminals*** of the cell have to be connected to the two terminals of the bulb. If any one terminal is left unconnected, the bulb does not glow.

This is why it is known as a circuit. Apparently, something electrical in nature comes out of the battery from one terminal and goes back to the battery through the other. Whenever there is a gap in a circuit, this electricity cannot get round it; it is then said to be an ***open circuit***. Can you now guess the purposes of a ***switch*** in a circuit?

Activity 2. Include a switch in a simple electric circuit containing one bulb and one cell. Find out how the switch can be used to turn on and off the bulb. It is convenient and safer while working with household electrical supply to hold the bulb in a ***holder*** or ***socket***. Sockets come in various shapes and sizes; examine some of them if available and notice how their terminals are connected inside to terminals of the bulb. A bulb in a holder is sometimes called a lamp. Use such a lamp in the simple circuit and find out how various types of switches also work in such a circuit.

CONDUCTORS AND INSULATORS

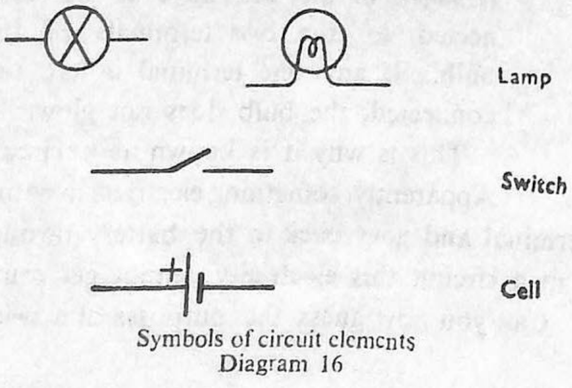
Are wires the only materials used to make a circuit complete? For example can any of the wires be replaced by a divider or a thread?

Activity 3. Make a closed circuit using one lamp, one cell and two wires. Now remove one of the two wires and use a divider instead. Does the lamp still glow? Test with other materials such as scissors, coin, paper pin and clip, thread, key and and key chain, glass rod, compass box, plastic scale, etc. You will notice that with glass rod and the plastic scale, the bulb does not glow.

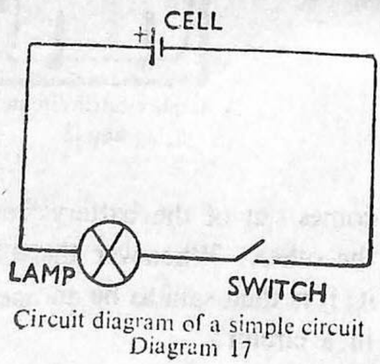
Materials which allow electricity to go through them are called good electrical conductors. Metals are all good conductors of electricity. Those materials which act to create gaps in circuits by not allowing electricity to pass through them are called ***insulators.*** Most non-metals are insulators of electricity. When a switch is off, the gap is filled by air; is air a conductor or an insulator?

CIRCUIT DIAGRAMS

Bulbs, wires, cells, switches, etc. all form elements of an electric circuit. We usually write certain symbols to show common circuit elements. Diagram 16 shows the circuit symbols of elements we have already employed. Using these symbols, the simple circuit we have already constructed can be shown as in diagram 17, this is called a ***circuit diagram.*** A more complicated electric gadget may contain many circuit elements.



Symbols of circuit elements
Diagram 16



Circuit diagram of a simple circuit
Diagram 17

Activity 4. Now take a cell and two lamps. Connect them as shown in diagram 18. What is the brightness of the bulbs as compared to that in the earlier experiment with one lamp? Reverse the cell, or a lamp, and you will notice that there is no difference in the glow.

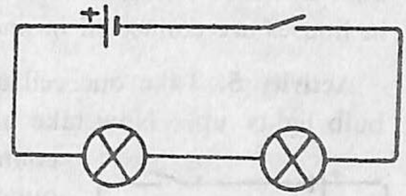
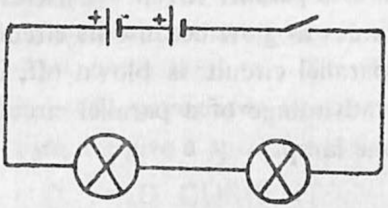


Diagram 18

Now add one more cell in the circuit. You will notice that the brightness of the lamps increases. Reverse one of the cells and observe that the lamps hardly show any glow. Draw a circuit diagram of the arrangement when the bulbs glow with the cells and two lamps. Many torches use three cells to give a powerful light; draw a circuit diagram of the electrical arrangement which employs three cells, a lamp and a switch.

SERIES CIRCUIT

When cells are added so that the brass tip of one touches the base of another cell, they increase brightness of the lamps. For example, in the above activity, the ***two cell + two lamp*** circuit which makes the lamps glow can be shown as in diagram 19.



A 2-cell + 2-lamps series circuit
Diagram 19

In this arrangement, the current which passes through one element passes through each of the other elements; such a circuit is called a ***series circuit***. Unscrew any one of the bulbs and you will notice that the circuit is broken. If one of the bulbs gets fused then the other will not glow. In the three-cell torch the cells are in series (diagram 20 *a*) and help to increase brightness of the lamps; if one of the cells is reversed (diagram 20 *b*) the cells are still in series but the brightness is considerably reduced. In fact, it is less than that for a two-cell torch. Can you guess the reason for this?

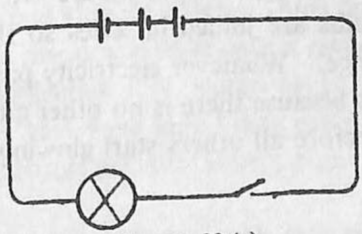


Diagram 20 (*a*)

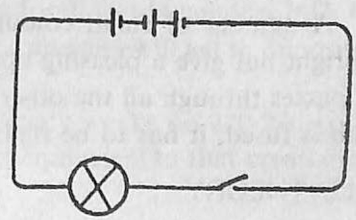


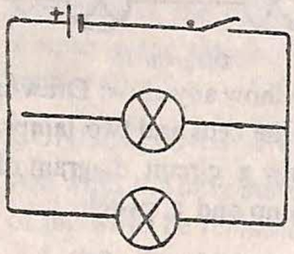
Diagram 20 (*b*)

PARALLEL CIRCUITS

In a series circuit if one bulb burns out, the entire circuit is affected. Also if we add one more bulb in the circuit the brightness of other bulbs decreases. Imagine

how annoying it would be if the lights in your room dimmed because someone next door switches on lights in his room. This is one reason why electrical appliances in houses are connected in another way.

Activity 5. Take one cell and one bulb and connect them with wires so that the bulb lights up. Now take another lamp with wires attached to its terminals, and connect it to the cell so that this bulb also lights up without disturbing the first circuit. Notice brightness of the two bulbs. The bulbs glow brighter in this case than when they were connected in series as in activity 2.



A parallel circuit
Diagram 21

Draw a circuit diagram of the arrangement you have made; this should look like diagram 21. Add one cell in series with the first and observe how the birghtness changes. Try connecting three bulbs in this way to one cell.

A branching circuit you have made above is known as a ***parallel circuit***. Unscrew one of the bulbs and you will see that the other continues to glow because its circuit still remains closed. If one of the two bulbs in a parallel circuit is blown off, it has no observable effect on the other. The second advantage of a parallel circuit is that one battery may be used to light more than one lamp.

DOMESTIC AND HOUSEHOLD CIRCUITS

The circuits used in a household supply as you would expect are parallel circuits. The circuits for each bulb, fan, radio, etc., branch out from the main terminal which is connected with the Power House; the Power House acts like a cell in the above experiments. In this way when any electrical gadget is switched on or off, other appliances are not affected. Moreover, since there is only one Power House, the only way to make all lamps light normally would be to connect them in parallel. Each appliance has an individual switch which is in series with it.

On the other hand, decoration lights for Diwali or Christmas are often connected in series. A number of small coloured bulbs are joined in series so that they are not very bright but give a pleasing appearance. Whatever electricity passes through one bulb, passes through all the other bulbs because there is no other alternate path. If one bulb is fused, it has to be replaced before all others start glowing again.

A SIMPLE THEORY

The fact that both terminals of a cell must be connected in a complete circuit suggests that something leaves the cell and a path must be provided for its return to the cell. It is rather like a circular car racing track. You can imagine a lot of cars going round and round the track and every time they pass the spectators' stand a lot of

cheering breaks out. Suppose also that the cars are such that on completion of each circuit they refuel at a petrol station before they start off again.

Now if no fuel is left, or the tracks are blocked by a pile up of cars, the racing would come to a halt and the cheering by spectators would also stop. In a similar way one can imagine little electrical cars going round the circuit and as they pass the lamps, the lamps light up and show that the cars are passing through. The electric cars then get into the cell to get refuelled to start round the circuit again with renewed energy.

This description of what might be happening inside the circuit is a suggestion only and perhaps very far from the truth but gives us some ideas of what may be happening inside. For example, if another parallel circuit with a bulb is connected to the first, it may work like another independent car track in which there are different spectators to cheer but the same petrol pump. The fuel would then get exhausted quicker, which is what actually happens to a cell. Also the cheering may be of a different type; in an electrical circuit the effect would be different if instead of the lamp we use a small electric fan.

Scientists always make models of this kind to explain their observations and help their understanding. We could improve or change this picture of electrical cars as we do more experiments and learn about electrical circuits. To these little electrical cars, we give a special name—***charge***.

P.D. AND CURRENT

You are perhaps aware that a torch cell is marked 1.5 volt. A volt is a unit of ***electrical pressure*** or ***potential difference*** (P.D.), which is responsible for driving the charges round in a circuit. The positive terminal of the cell marked + (brass cap) is considered at a higher potential as compared to the negative terminal (zinc container); the charges are pushed from positive to the negative pole of the cell through the external circuit, which is indicated by arrow-heads in a circuit diagram.

If two cells are joined in series, they would create double pressure, and a lamp in series would glow brighter. Three cells in a torch would create a P.D. of 4.5 volts. However, if one of the three cells is reversed, its pressure will act in opposite direction; hence, the effective P.D. would be 1.5 volt.

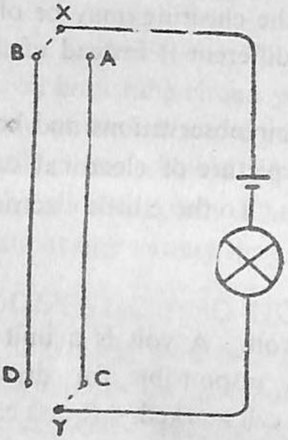
You may also have heard that the mains supply works on 220-230 volts. In this case the electrical pressure is very high, almost equivalent to that created by 150 cells in series!

You have observed that with two cells, the glow in one lamp is more than with two lamps in series. P.D. is therefore not the only factor which governs the glow in lamps. The glow is an indication of the flow of charges; the rate at which the charges flow through a circuit is called a ***current***.

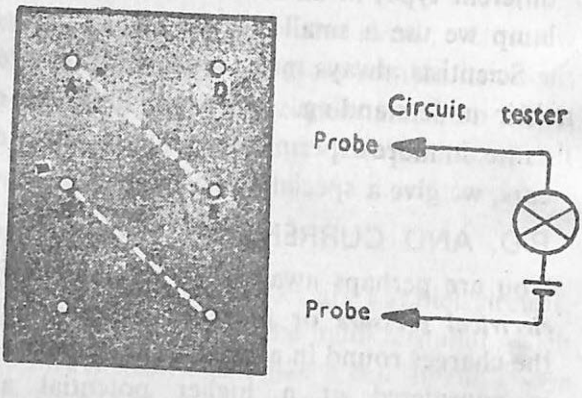
CIRCUITS FOR FUN

Electrical circuits with a few lamps, switches and cells provide lots of fun. A few are given below and you could design some more yourself.

Activity 6. A useful circuit to construct is the staircase arrangement for switching on and off one bulb from two positions. It requires special switches which are two-way-type, with arrangement for connecting one wire to either of two paths. If X is connected to A, and Y to C, the lamp glows. The lamps could be switched off from both ends at will. Suppose X is disconnected from A and connected to B (diagram 22); the lamp can then be switched on again from Y end by disconnecting it from C and connecting it to D.



Circuit for staircase lighting
Diagram 22



A Puzzle card
Diagram 23

Activity 7. Take a small piece of cardboard and fix on it six terminals A to F as shown in diagram 23. The terminals can be connected internally in a variety of ways and covered up. How could one find out the internal connection without exposing them to view? A lamp and a cell may be used to solve this puzzle. For example, with the connections as shown in the diagram, the lamp will light when terminals A and E, or B and F are included in a series circuit. Make a number of such cards for a party game.

Activity 8. You may have seen quiz circuits in which a lamp glows when two words are matched. Here is an arrangement for a simple circuit in which four pairs of words are to be matched. As the circuit makes it obvious, this is very much similar to the card in diagram 23 except that the cell and lamp are fixed on to the card with two probes X and Y coming out of the quiz board (diagram 24).

The bulb glows when the circuit is closed as the probes touch terminals connecting a question and its answer or any other type of quiz.

While the activities and information given here may be useful to understand electric circuits and functions of their elements, it is very important to remember that without a good understanding one should not attempt to handle electrical appliances connected to domestic supply system; this could be fatal. It is safe to work with cells which will never give any shocks.

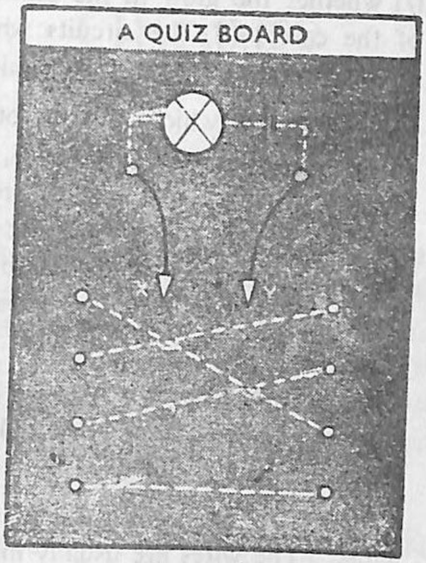


Diagram 24

PROBLEMS

1. Diagram 25*a* shows the circuit containing one lamp, one cell and a switch. Name these elements.

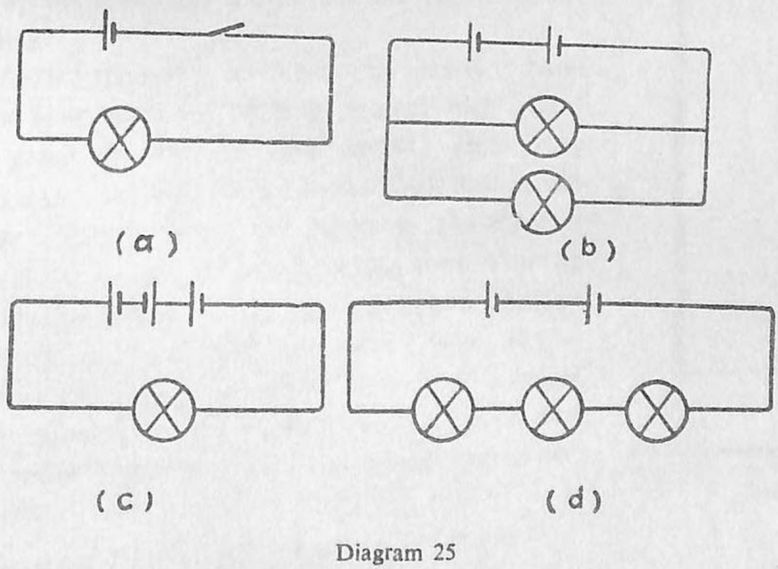


Diagram 25

When the switch is closed in (*a*), the lamp glows with normal brightness. If identical lamps and cells are used in circuits shown in (*b*), (*c*) and (*d*), state :

(*i*) whether the glow in the bulbs will be dimmer, normal or brighter in each of the cases; (*ii*) the circuits which show series arrangements; (*iii*) in which circuit will the cells run down quickest, and in which circuit slowest?

2. In diagram 26 which bulb or bulbs will glow, if at all, when : (a) switch S_1 alone is closed; (b) switches S_1 and S_2 are closed; (*c*) switches S_1 and S_3 are closed; (d) switches S_2 and S_3 are closed; (e) all the three switches are closed. State whether the two lamps are in series or parallel arrangement.

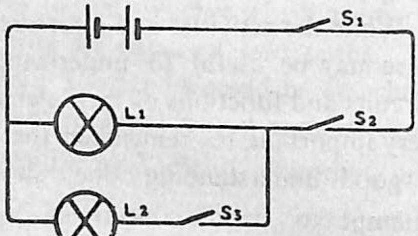


Diagram 26

3. Give two reasons why parallel arrangement of electrical appliances is desirable in domestic supply system.

4. Plastic, rubber or varnish are some of the materials used to cover electrical wires. The wires are usually made of copper, aluminium, etc. State whether these materials are conductors or insulators of electricity.

4 Temperature and Volume Change

Heat energy causes many changes in objects. When a solid changes to liquid, or a liquid to gas, this change can be easily noticed. When it increases or decreases the temperature of an object we could touch it and feel the difference; alternatively, a thermometer could be used to note the change in temperature. Actually, the level of liquid in the thermometer stem rises due to an increase in volume of the liquid. One of the most important effects of heat on a substance is its expansion. Most materials expand in volume with rise of temperature, and contract on cooling.

EXPANSION OF GASES

Activity 1. Fix a tight-fit rubber cork and tube into a 500 ml flask and support it as shown in diagram 27. Place a beaker filled with water under the open end of the tube and warm the flask gently over a flame. You will notice air bubbles coming out of the water showing thereby that air expands on heating. Now allow the flask to cool, and water is seen to rise up the tube; this shows that air contracts on cooling.

Diagram 27

Wait till the water level becomes steady. Now warm your hands by rubbing against each other and grasp the flask in your hands. Heat from your hands expands the air in the flask and forces water noticeably down the tube. If the flask is cooled by passing running water over it or by holding a few cubes of ice around it, the air contracts and water level rises up the tube. If you observe the water level carefully against a scale held next to it over a larger period of time, you will realise how the volume of air changes during the day.

EXPANSION OF LIQUIDS

Activity 2. Add some flourescein or coloured ink to water in a trough to make

it clearly visible. Fill a 500 ml flask with it and fix on it a tight-fit rubber cork and tube. The water would rise a short way up the tube. Mark the level of water on a white sheet of paper held against the tube. Observe carefully any movement of the water level as the flask is immersed in a trough filled with hot water (diagram 28).

It is noticed that the water level first drops slightly and then rises considerably. If the flask is taken out of the trough and allowed to cool (immersing it in ice-cold water will greatly help) then the level falls back.

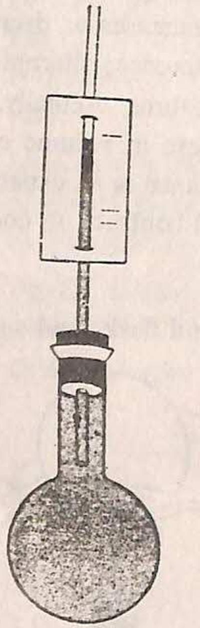


Diagram 28

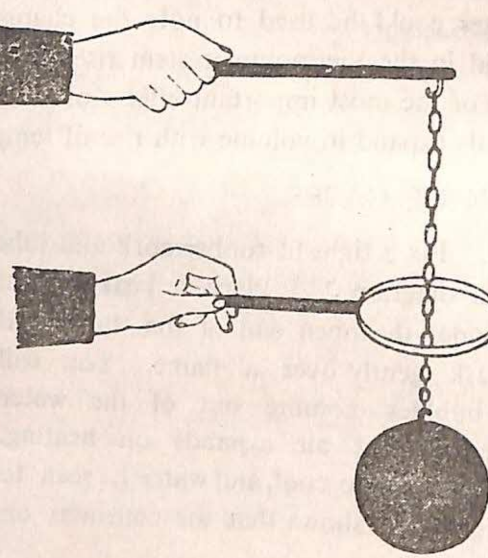


Diagram 29

EXPANSION OF SOLIDS

The slight drop of water level in the above experiment is caused by expansion of the flask when heated; the flask expands in volume first due to direct contact with hot water. The experiment also shows that water expands much more than glass. The expansion of solids is rather small, and carefully arranged experiments are required to show this effect.

Activity 3. A ball and ring apparatus (diagram 29) can be used to show the expansion and contraction of a solid due to changes in temperature. At ordinary temperature the ball just passes through the ring. When the ball is heated over a flame, it does not pass through the ring; however, if the ball is cooled, it contracts and now passes through the ring.

Now heat the ring and find out if the hole becomes bigger or smaller. This can be done by heating both the ring and the ball and observing if the ball passes through

the ring. It is seen that the ring allows the ball to pass through easily when hot; this shows that both the inner and outer diameter expand on heating. This property is put to good practical use when a metal tyre is to be put on a cart, train or axle wheel in machines; the tyre just slips on the wheel when hot and tightly grips the wheel when it cools.

Activity 4. To show the tremendous forces that come into play during expansion and contraction, a dramatic experiment can be performed using a bar-breaker apparatus (diagram 30). It consists of a strong iron frame holding a steel rod. One end of the rod is threaded so that it can be screwed up; through a hole near the other end is slipped a rod made of glass or wrought iron. The rod is first heated strongly and the nut tightened. As the rod contracts on cooling, it exerts a strong inward force which breaks the glass or wrought iron rod into pieces.

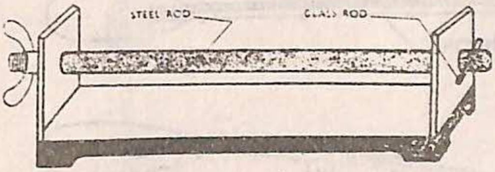


Diagram 30

EVERYDAY EXAMPLES OF EXPANSION

Weathering is an example in nature of the effect of expansion and contraction of rocks which break into small pieces. If very hot liquid is poured in glass jars and tumblers, they are likely to crack. They suddenly expand inside causing great force. Special kinds of glass are now available which expand very little; as a result, the force developed is too small to break objects made from them. Telegraph wires are seen to sag between poles during summer due to their expansion.

Concrete roads, bridges and iron rails for trains are never made in one continuous piece but in short lengths. Without the gaps they might bend or bulge during summer. Long pipelines often have special sections to permit expansion and contraction without breakage. Pistons in car and scooter engines are fitted with springy rings so that while they hold the cylinders firmly during up and down movement, the expansion of pistons due to heat is accounted for.

BIMETAL STRIPS

Different materials of the same length have different rates of expansion. An important application of this property is the bimetal strip.

Activity 5. A straight bimetal strip which has two equal lengths of brass and iron riveted firmly together is taken. If it is heated or cooled considerably, it bends. When heated the brass strip is on the outside of the bent curve because brass expands more than iron (diagram 31).

The bending effect is used in a ***thermostat*** to control temperature of electric irons, refrigerators and other automatic electrical appliances. Diagram 32 shows a thermostat

fitted to an electric iron. At ordinary temperature the brass section of the bimetallic strip makes contact with the terminal, thus switching on the heater circuit. When the element of electric iron attains a desired temperature, the strip bends upwards sufficiently to break contact. As the iron cools down, the strip gradually returns to normal shape and touches the terminal. This switches on the iron again. A screw S enables a required setting for temperature by moving the terminal up and down.

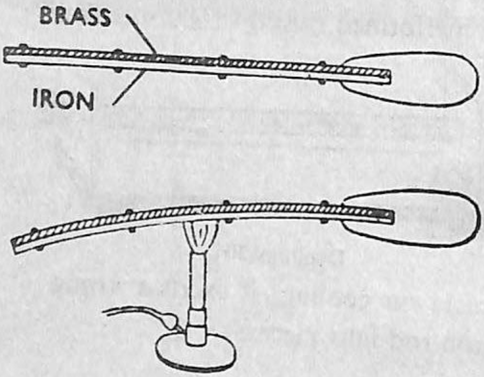


Diagram 31

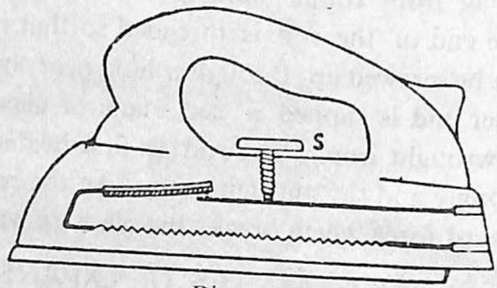


Diagram 32

Among the other applications of this bimetallic strip are flasher unit employed in cars, fire alarm and time control of clocks and watches. A watch keeps time by the swinging of a balance wheel; when the spring becomes weak and diameter of the balance wheel increases due to expansion in summer, the watch would go slow. A bimetallic balance wheel (diagram 16) ensures that temperature has no effect on these two factors.

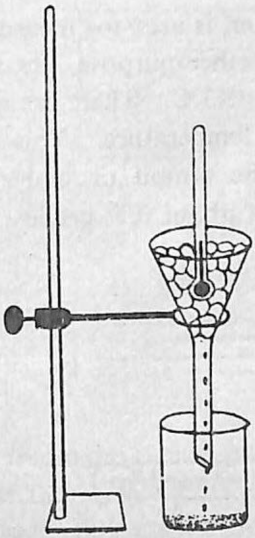
THERMOMETERS

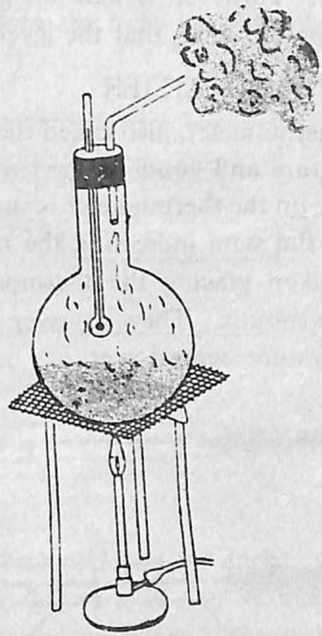
A thermometer is an instrument specially designed to measure temperatures of objects. The most common forms of thermometers contain a liquid, mercury or alcohol, as the material. It is based on the principle that materials expand when heated and contract when cooled. Most of the liquid is in a bulb; the thermometer therefore gives temperature of an object around the bulb. A thermometer also has a very narrow stem which contains very little liquid; it is sealed at the top when all air is driven out of the space at the top. The stem is marked to measure the temperature.

Like all other units of measurement such as second, metre, kilogram, etc. the °C is a "man-made" unit of temperature measurement.

The temperature of pure melting ice and of steam above boiling water at sea level are called the lower and upper fixed points, and are marked as 0° and 100° on the Celcius scale. By fixed points we mean that under given conditions the temperatures are always the same and hence reproducible.

The distance between these two marks is then divided into hundred equal parts, each division representing a degree Celcius of temperature change. In this marking it is assumed that equal changes of temperature produce equal increases in volume of the liquid, and that the stem of the thermometer is uniform.





Marking lower and upper fixed points

Diagram 33

Diagram 34

SENSITIVITY

A thermometer is sensitive when its degrees are far apart, *i.e.*, even small changes in temperature could be noticed. Sensitivity can be increased by (*a*) increasing size of bulb, hence volume of liquid in it, so that the volume increase for a given temperature change is more; (*b*) reducing the bore of the stem, so that, for a given increase in volume, the liquid thread moves greater distance; and (*c*) using a liquid which has a greater expansion rate; in this respect alcohol is more suitable than mercury.

LIQUIDS IN THERMOMETERS

Mercury is most commonly used in thermometers because—

(*a*) It remains a liquid over a wide range (from —39°C to +357°C) of temperature, and hence can be used over most of this range;

(*b*) Its expansion is uniform over most of this range;

(*c*) It is a good conductor of heat; therefore, it quickly responds to changes of temperature;

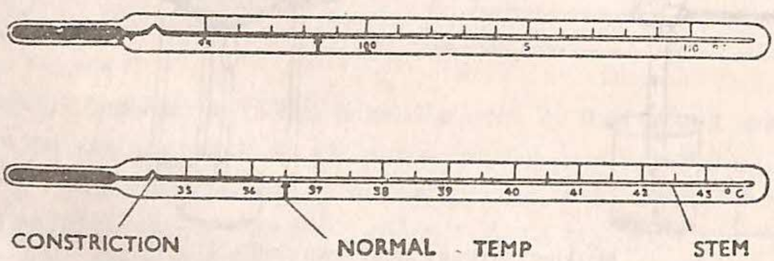
(*d*) It is opaque; hence, its level can be read easily;

(*e*) It does not wet the glass stem; therefore it gives quick and accurate reading.

In cold countries and for low temperature readings, alcohol is used as the thermometric material; it freezes at as low a temperature as —117°C. Alcohol also has the advantage that its expansion rate is about seven times that of mercury; it is therefore more sensitive. However, it wets the glass and has a low boiling point (+78°C); it is coloured blue or red so that the level can be read easily.

CLINICAL THERMOMETER

The clinical thermometer, also called the doctor's thermometer, is used for measuring body temperature and contains mercury. Since it has no other purpose, the temperature range on the thermometer is short: from about 35° to 43°C. There is a mark at 36.5°C on the stem indicating the normal human body temperature. This temperature is taken placing the thermometer bulb under the armpit or under the tongue in the mouth. They however show a difference of about 0.5° celcius, the armpit temperature being lower.



Clinical or Doctor's thermometer
Diagram 35

The thermometer has a kink or constriction near the bulb (diagram 35). When the bulb is placed under the armpit, expansion of mercury forces it through this narrow portion up the stem. When removed from the armpit, the mercury contracts; but this breaks the mercury thread at the constriction while holding the level in the stem. Thus a correct reading of body temperature can be made even after some time. The mercury thread can be re-set by giving the thermometer a quick jerk. This thermometer cannot be ***sterilised*** by placing it in hot water for the force of expansion of mercury would break the thin glass tube. The glass tube has necessarily to be thin so that although glass is a bad conductor of heat, body heat would quickly reach the mercury inside.

OTHER THERMOMETERS

At times we want to know the highest or lowest temperatures attained during the day, but recorded at some later time. For example, the lowest temperature reached at night can be read conveniently only the following morning; the highest temperature during the day may be attained when we may not be looking at the liquid level.

The need for continuous observation is avoided by a clever arrangement in these thermometers. The maximum thermometer uses mercury as the liquid. A small iron index with a spring attached to it holds the tube above the mercury level in the stem (diagram 36*b*). When mercury expands, the index is pushed up the stem but holds to it when mercury contracts. The end of the index near the bulb registers the highest temperature reached.

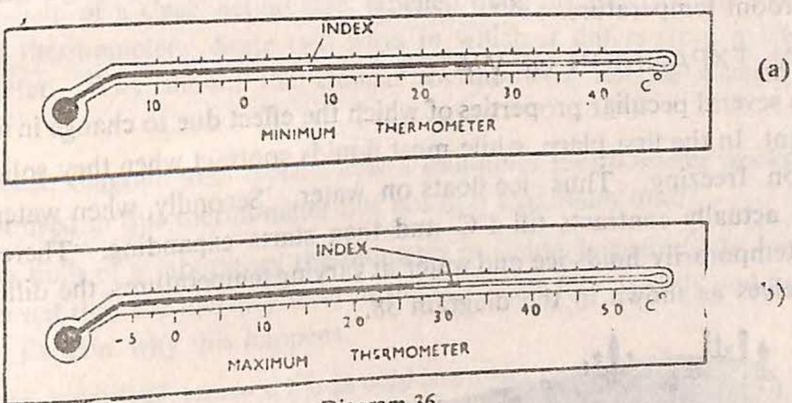


Diagram 36

The minimum thermometer uses alcohol as the liquid and the index is inside the level of the liquid (diagram 36*a*). When temperature falls and alcohol contracts, its surface, acting as a stretched skin, pulls down the index. The index stays in position when temperature rises and alcohol expands. The end of the index away from the bulb registers the minimum temperature reached. In both these thermometers, a magnet is used to re-set the index.

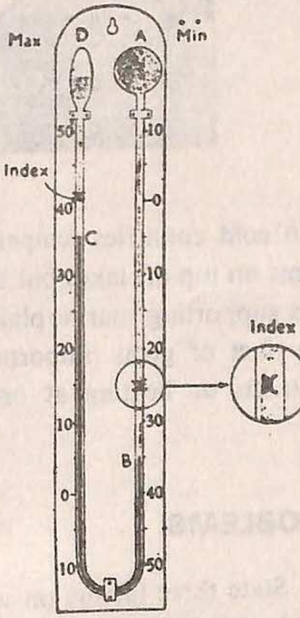


Diagram 37

MAXIMUM AND MINIMUM THERMOMETER

The maximum and minimum thermometer serves a double purpose: to measure and record maximum temperature during day and minimum temperature at night. The bulb *A* (diagram 37) contains the thermometric liquid alcohol, whose change in volume with temperature is primarily responsible for registering the minimum and maximum temperatures. *BC* section contains mercury; above *C* there is alcohol which partly fills the bulb *D*, leaving the space above it empty to allow for expansion.

When alcohol in *A* expands due to rise in temperature, it pushes the mercury section, thus

sending a steel index above level C upwards. The index enables the maximum day temperature to be read on the scale marked along the limb. When alcohol in *A* contracts due to fall in temperature at night, the mercury is drawn back pushing the steel index above *B* upwards. The index therefore gives the minimum temperature reached during night, and it can be noted on the scale marked along this limb.

At any time of the day, mercury level in both the limbs is always the same and gives the room temperature.

UNUSUAL EXPANSION OF WATER

Water has several peculiar properties of which the effect due to change in temperature is significant. In the first place, while most liquids contract when they solidify, water expands on freezing. Thus ice floats on water. Secondly, when water at 0°C is heated, it actually contracts till 4°C and then starts expanding. Therefore, when a beaker temporarily holds ice and water at varying temperatures, the different layers set themselves as shown in the diagram 38.

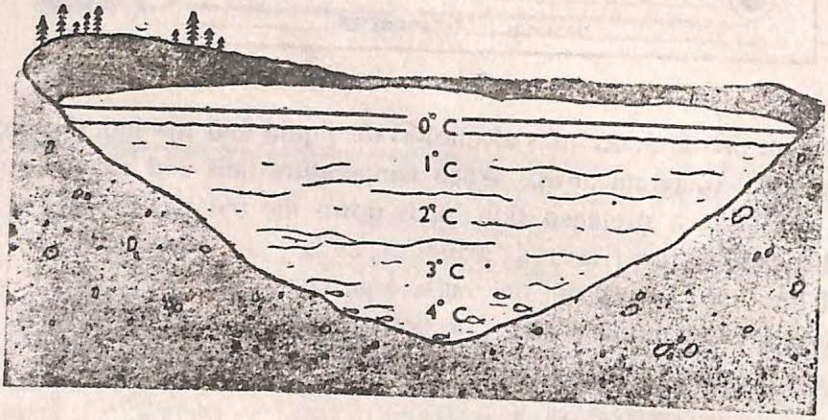


Diagram 38

In cold countries temperatures fall several degrees below zero. Thick ice sheet forms on top of lakes but the water below may remain at 4°C throughout winter thus supporting marine plants and animals. Thus the unusual expansion of water is a fact of great importance in nature. Rubber is another material which contracts on heating at ordinary temperature.

PROBLEMS

1. State three factors on which the expansion of a solid depends. Why are rivets heated before being hammered into position?

2. Why does a bimetallic strip curve when heated? Show by drawing a clear diagram how such a strip can be used to operate a thermostat keeping the temperature of hot water between 70°C and 80°C.

3. What is meant by the lower and upper fixed points of a thermometer? Draw diagrams to show how these are marked on a mercury thermometer. Which conditions are necessary to obtain accurate markings of the fixed points?

4. With the help of a clear, actual size, labelled diagram, describe the working of a clinical thermometer. State two ways in which it differs from a laboratory thermometer. Why should the clinical thermometer not be washed in hot water?

5. Draw a clear diagram and explain how a minimum thermometer works. Why is alcohol used in this thermometer but not in a maximum one?

6. When the bulb of a laboratory thermometer in suddenly placed into hot water, it is observed that the mercury level in the stem first falls slightly and then rises rapidly. Explain why this happens.

7. How is the survival of acquatic life in cold countries dependent upon the peculiar nature of expansion of water?

5 Experiments with Pressure

You are well acquainted with change of seasons. During summer, water from the seas evaporates and changes into clouds. Winds bring these clouds over the thirsty land and the clouds turn into monsoon rains. The land gets soaked with water, and the rivers ultimately carry away the water back to the seas. Why does this large scale movement of water in rivers and of clouds in the sky take place?

Let us take an everyday example. People living in top stories of buildings often complain that they do not get enough water at the taps. Some buildings have pumps fitted to them which lift water up to a high level; the water is raised up to create the required ***pressure*** at the taps.

PRESSURE AND FLOW

Most of you have seen gas cylinders being used in houses. Why does gas come out of them when the tap is opened? When a cylinder supplies no more gas, we say it is empty. In this condition, is there no gas at all inside, ***i.e.***, is there a vacuum?

Activity 1. Blow a balloon with plenty of air in it. Now prick it with a pin. The balloon explodes with a sound similar to a tyre burst. How does movement of air take place?

You would realise that there is a sudden rush of air from inside to outside. When a lot of air is squeezed into the balloon, the ***pressure*** inside has been increased in comparison to that outside. As soon as an opening is created by the prick of a pin, the air at high pressure rushes out. Thus, difference of air pressure is the cause for its movement.

In cooking gas cylinders, almost 15 kg of gas is compressed initially. When the tap is opened, excess pressure inside causes the gas to flow out freely. As the gas is used up, this difference in pressure gradually becomes less. When no more gas comes out, a "pressure balance" is achieved.

WHAT IS A PRESSURE GAUGE?

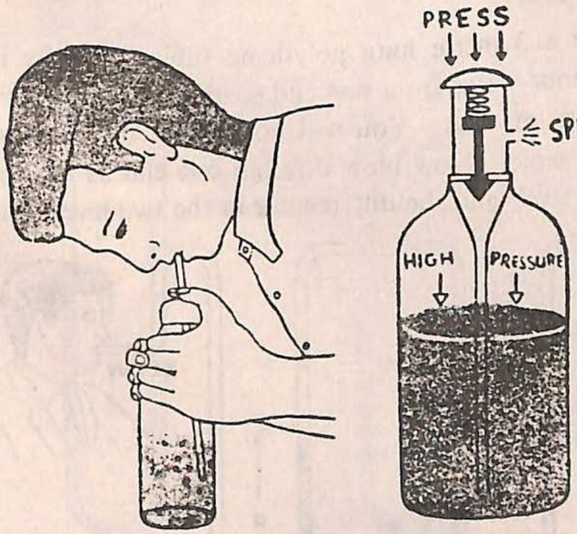
You are well aware that tyres have to be "inflated" with air. Those who own a scooter or car may have noticed that the excess pressure in a tyre is measured by a meter called a ***pressure gauge.*** When you have a flat tyre, the meter reads zero; this means that the pressure of air inside is the same as that outside. How does a pressure meter work?

In order to measure excess pressure, it must cause some noticeable effect which we can record. One of the effects we ha e seen is a flow of liquid or gas.

Activity 2. Partly fill a soda bottle with water and fit a tight-fit cork on its mouth through which passes a glass tube open at both ends (diagram 39 *a*); make sure that the bottle is air-tight. Now blow hard into the tube and quickly close the top end of the tube with your finger.

You will observe that as you blow through the tube, air bubbles out of the lower end of the tube. The harder you blow, more is the air squeezed at the top of the bottle. The pressure of this compressed air now exceeds that of air outside. How could you test this?

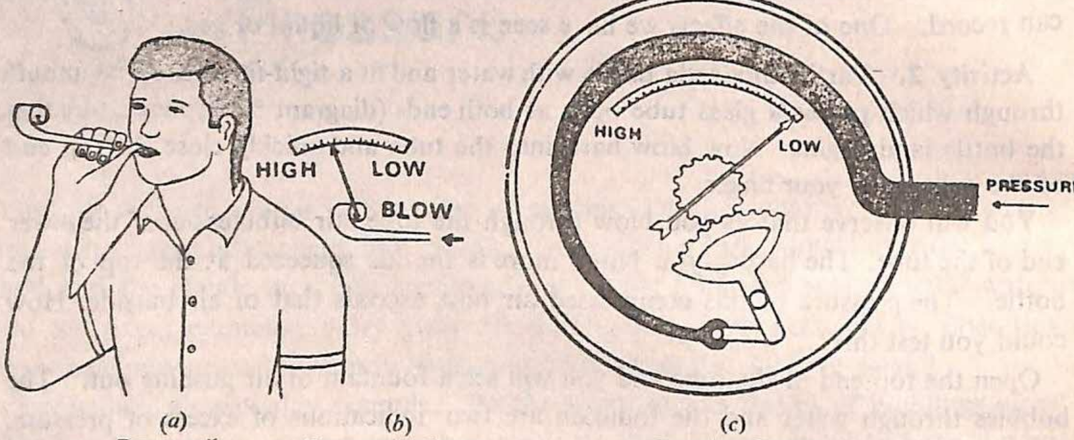
Open the top end of the tube and you will see a fountain of air gushing out. The bubbles through water and the fountain are two indications of excess of pressure. Incidentally, this principle is used for a soda siphon, hair sprayer (diagram 39 *b*), etc.



(*a*) (*b*)

Diagram 39

You have perhaps seen or used a paper toy (diagram 40 *a*) which children play with on birthday and new year parties. When we blow through the open end, the paper spring uncoils itself due to increase of pressure. When we do not blow, the inside pressure equals that of outside and the paper coils back. If a pointer were to be attached at the centre of this paper spring (diagram 40 *b*), it will move along a scale indicating changes in applied pressure. The ***Bourdon Pressure Gauge*** (diagram 40 *c*) used by engineers is a device which works on this principle.

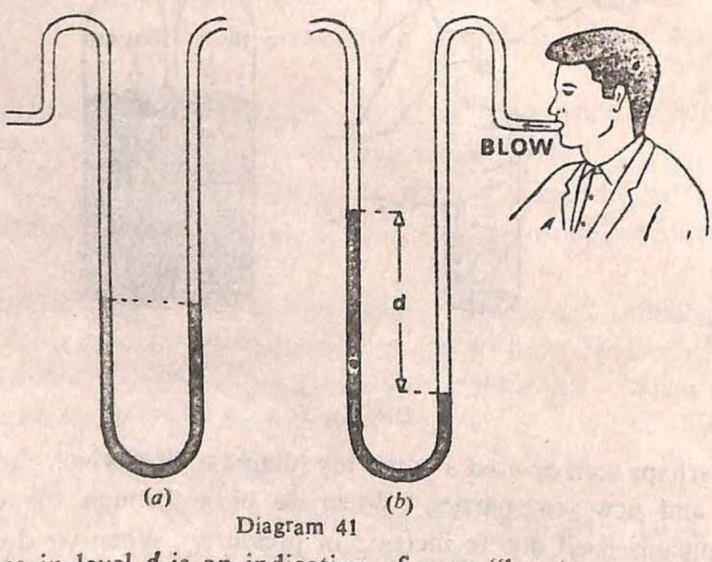


(a) Paper coil (b) Pressure indicator (c) Bourdon Gauge

Diagram 40

LIQUID MANOMETER

Activity 3. Take a 3 metre long polythene tubing and fix it vertically in the form of a U-tube; pour water from one end so that the water level is about 50 cm above the base (diagram 41 *a*). You will notice that the horizontal level of water in both limbs is the same. Now blow through one end as hard as you can. Note the change of water level, and the difference *d* in the two levels (diagram 41 *b*).



(a) (b)

Diagram 41

The difference in level *d* is an indication of your "lung" pressure; it shows how much pressure your lungs can build up in excess of outside air pressure. Repeat the experiment blowing through the other end, and you will realise that water is pushed down in that limb but the difference in level remains unchanged.

Activity 4. There are two other extensions of this experiment which you should try. Connect one end of the tube to the laboratory gas tap. The water column in the limb joined to the gas supply will be pushed down (diagram 42 *a*). The water column *p* will indicate the excess gas pressure. You can compare the gas tap pressure with your lung pressure.

Now replace water in the tubing with a liquid of low density such as kerosene or turpentine oil. Connect one limb to the gas tap again and note the liquid column supported by the excess pressure. You will notice that the difference in liquid levels is not the same now. A less dense liquid will require a greater column to achieve a pressure balance.

Next set up a similar U-tube using two polythene tubings of different diameters joined near the base (diagram 42 *b*); the initial level of water in the two limbs remains equal. Now connect one end of the tube to the gas tap, and then the other end. You will observe that the liquid column supported by the excess pressure is the same either way; the different diameters of the two limbs containing different quantities of the liquid do not matter.

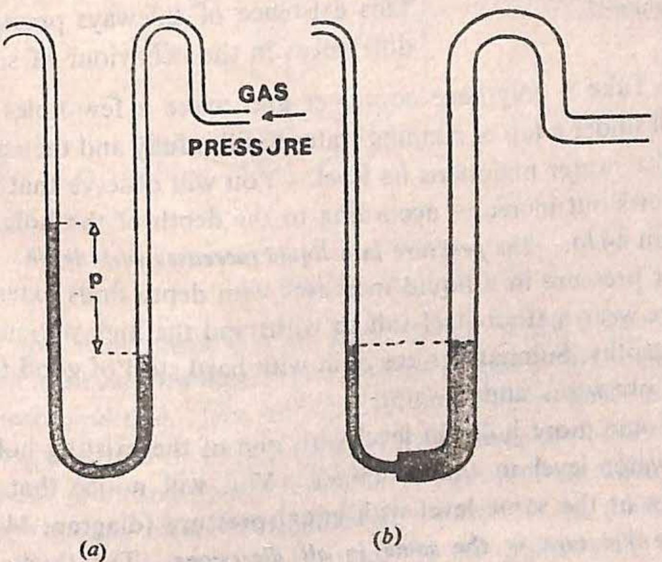
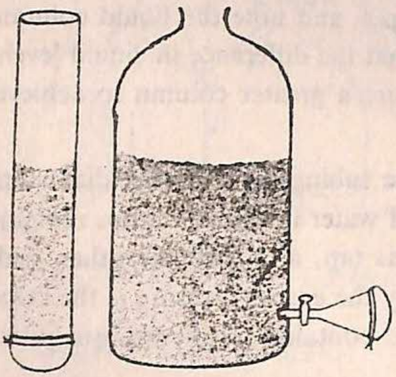


Diagram 42

This U-tube liquid apparatus, which indicates difference of pressures acting on the liquid surfaces in the two limbs, is called a ***manometer***. To compare small differences in pressure, a liquid of low density is used because it creates a greater column of the liquid; thus, sensitivity of the instrument is increased. It may be noted that the diameter of the limbs is of no consequence, except that a wider tube will require more liquid.

LIQUID PRESSURE

Activity 5. Take a wide glass tube open at both ends and tie a thin rubber membrane at its lower end. Pour some water in the tube and you will notice that the membrane bulges downwards (diagram 43 *a*). This shows that liquids exert pressure on the base of a vessel in which they are contained.



(*a*) (*b*)
Diagram 43

Activity 6. Take a bottle which has an opening from the side just above the base. Use a tight-fit cork to fix a funnel into the opening and cover the mouth of the funnel with a thin rubber membrane. Now pour water in the bottle and you will notice that the membrane bulges outward, showing that it is being pressed from inside (diagram 43 *b*).

The experiments show that liquids exert pressure not only on the base of a container in which they are kept but also on the walls of the container. This existence of sideways pressure is one of the differences in the behaviour of solids and liquids.

Activity 7. Take a polythene container and make a few holes in it at different levels. Hold it under a tap of running water to fill it fully and then adjust the opening of the tap so that water maintains its level. You will observe that the pressure with which water flows out increases according to the depth of the hole under the water surface (diagram 44 *b*). ***The pressure in a liquid increases with depth.***

The fact that pressure in a liquid increases with depth finds extensive application. Deep sea divers wear a stout steel suit to withstand the high pressure which acts on them at great depths. Submarines are built with hard steel of good thickness to withstand the high pressures under water.

Now make some more holes in level with one of the existing holes and as before maintain the water level in the container. You will notice that the water flows out of the holes at the same level with equal pressure (diagram 44 *a*). ***Thus, at the same depth the pressure is the same in all directions.*** The thickness of a dam is made broader at the base so that it can stand the high pressure acting sideways as depth of water increases.

TRANSMISSION OF LIQUID PRESSURE

Activity 8. Make some holes on various faces of the polythene container. Fill the container completely with water and close its mouth with the cap. Press it hard with your hand; you will notice that water spurts out in all directions (diagram 44 *c*). The water comes out with equal pressure through all the holes.

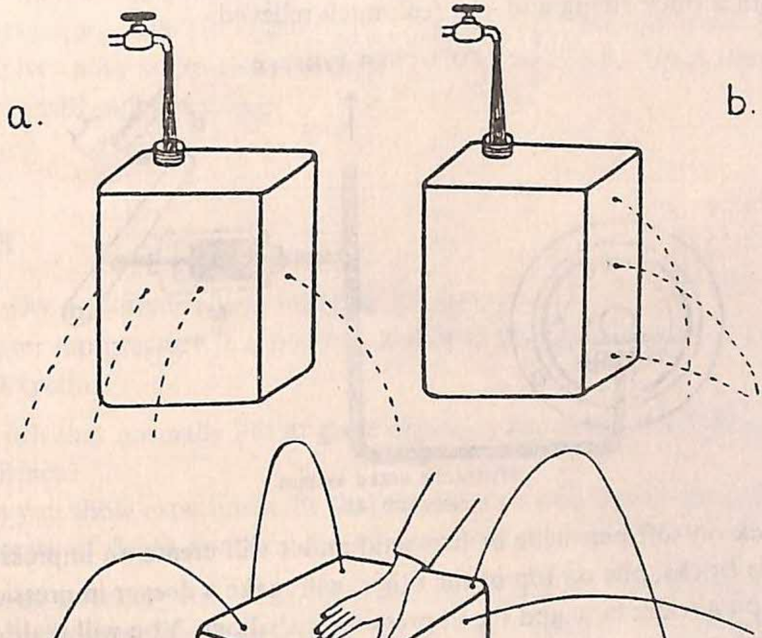


Diagram 44

The result of this experiment can be summed up in the form of a law : ***When pressure is applied to an enclosed fluid, it is transmitted equally to all parts of the fluid. This is called Pascal's principle.*** The principle is applicable to gases as well.

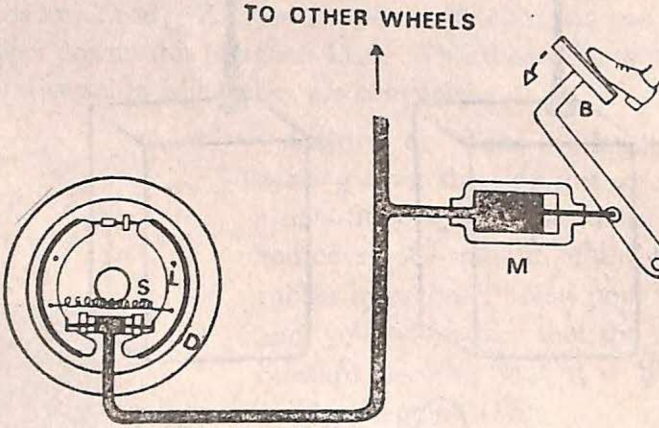
An important application of transmission of liquid pressure is in the construction and use of hydraulic press and hydraulic brakes. Diagram 45 shows how the hydraulic brakes work. By stepping on the brake pedal *B*, a piston in the master cylinder *M* is pushed. The pressure is transmitted through the oil pushing the break shoe and lining *L* against the rotating brake drum *D*; this brings the vehicle to a screeching halt. When pressure on the brake pedal is released, the spring *S* pulls back the shoe.

FORCE AND PRESSURE

Do you know why camels can walk without much difficulty in sandy deserts? What would happen if nails had sharp points at both ends?

Activity 9. Hold a thumb tack between your two fingers and press it as hard as you can. You will feel it painful at the sharp end and there will be a deep mark due

to it. It is very painful to carry a heavy parcel holding it with a thin string; hold the same load with a thick string and you feel much relieved.



Hydraulic brake system
Diagram 45

Place a brick on soft plasticine or fine sand and it will create an impression on the surface. Two bricks, one on top of the other, will make a deeper impression. Now place a brick on a wider base and the impression is shallow. You will realise that the depth of impression is different due to different pressures acting on the surface. Greater load (or a greater force) increases the pressure while a larger surface area decreases the pressure.

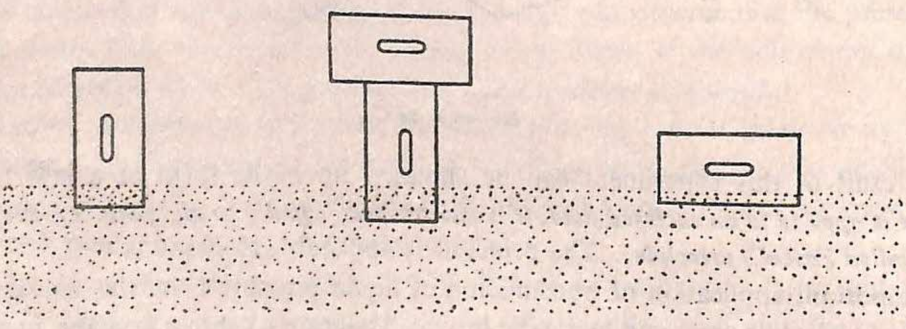


Diagram 46

The three quantities force, pressure and area are related in a simple way which can be expressed mathematically as under:

$$\underset{(\text{N/m}^2 \text{ or g-f/cm}^2)}{\textbf{\textit{Pressure}}} = \frac{\textbf{\textit{Force}} \text{ (N or g-f)}}{\textbf{\textit{Area}} \text{ (m}^2 \text{ or cm}^2)}$$

This explains why flat-footed camels can walk easily in sandy deserts. Heavy tractors can go through marshy land and muddy soil easily because their rear wheels have large area. The caterpiller tracks of tanks and huge excavators help them to

negotiate any uneven and sinking ground because the pressure exerted on the ground is comparatively less. On the other hand, cutting and piercing tools like saws, needles and knives have sharp points or blades so that they exert great pressure with comparatively small applied force.

PROBLEMS

1. Explain why a footballer uses studs on his boots.
   Is the water tap pressure in a building higher at the top storey or at the ground floor? Explain.
2. Why do fish that normally live at great depths in the ocean burst when brought to the surface?
   How can you show experimentally that the pressure of a liquid column increases with increase of depth and increase of density of the liquid?
3. The base of a rectangular vessel measures $10 \text{ cm} \times 8 \text{ cm}$. A liquid of density 0.8 g/cm^3 is poured into it to a height of 20 cm. What is the pressure exerted on the base?
4. Why does a bubble of gas coming up from the bed of a lake get bigger in volume as it gets nearer the surface?
5. Why do trucks and heavy vehicles have four or more rear wheels? A car has its tyres at a pressure of 1.5 Kg-f/cm^2. What differences, if any, will there be on the tyre pressure, and on the area of tyres in contact with ground, when the car is heavily loaded? Explain.
6. A test tube is inserted mouth-down into a trough of water so that no air escapes from the tube. State what changes if any take place in the following cases: (*a*) the volume of air in the test tube; (*b*) the weight of air in the test tube; (*d*) the mass of air in the test tube; (*d*) the pressure of air in the test tube; and (*e*) the density of air in the test tube.

6 Atmospheric Pressure

ATMOSPHERIC PRESSURE

The air envelope surrounding the earth is called the atmosphere. It is comparatively dense near the earth's surface, and becomes rarer at high altitudes. The pressure of atmosphere is due to the weight of the air column acting on a specified area at any place. Due to transmission of fluid pressure, at any point this pressure acts equally in all directions.

Activity 1. Press a rubber sucker against a window pane till it becomes almost flat. Now try to pull it out. You will find that it is very difficult to pull it out because of the atmospheric pressure pushing it against the window pane. Because of the expelled air, there is no opposing force present to reduce the pressure difference.

The atmospheric pressure decreases on high altitudes because the air column above these places is short and rare. Jet planes nowadays fly at an altitude of about 10,000 metres; there is so little air there that these planes are all "pressurised" so that we can withstand the low pressure and also breathe normally. Our body is not suited to conditions of very low and very high pressures. Space travellers in satellites and those who landed on the moon could come out of their vehicles only when they were wearing space suits which are "pressurised" from inside.

Change of atmospheric pressure at a place causes wind movements. Meteorologists, who forecast weather, keep track of wind movements by gathering data on air pressure and other weather factors of a region; the information is plotted on special weather maps.

MERCURY BAROMETER

The air pressure at a place can be found out by reading an instrument called a barometer. The U-tube can be used to find out the atmospheric pressure at a place in terms of mercury column.

Activity 2. Take a 1 metre tall U-tube and fill it about half with mercury. Now connect one end to an exhaust pump. When all the air from this limb is taken out, mercury rises to "balance" the atmospheric pressure (diagram 47 *a*). The pressure at the level P due to atmosphere is equal to the pressure acting on common level Q, which is entirely due to h cm of mercury column. At sea level under normal conditions this mercury column is 76 cm.

Activity 3. A comparatively difficult method, but employing no costly apparatus, is to set up a *simple barometer.* Take a 1 metre long, narrow bore and stout glass tube closed at one end, and fill it completely with mercury. The tube should be tapped to ensure that there are no air bubbles inside. Now close the top end with a finger, carefully invert the tube so that the open end is inside a bowl of mercury and gradually release the finger.

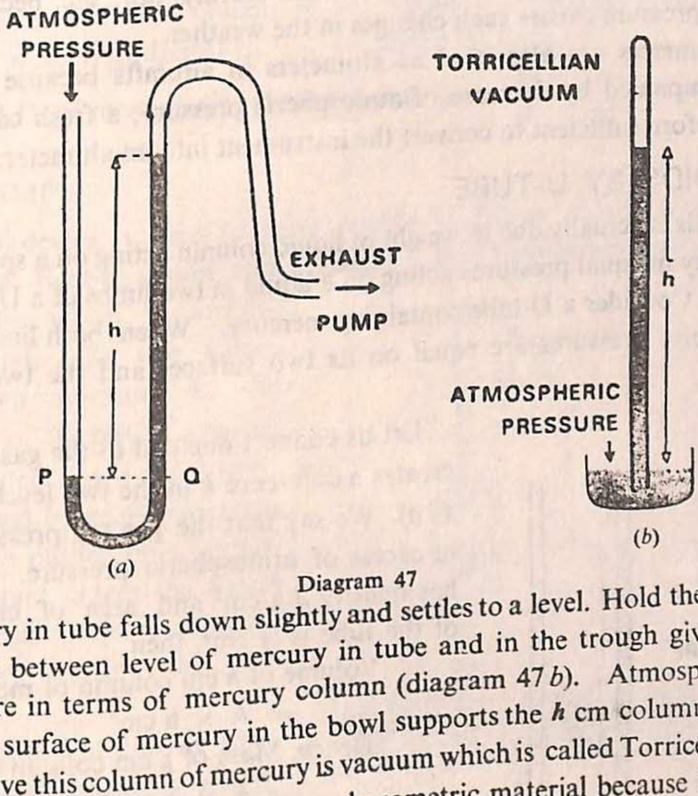


Diagram 47

The mercury in tube falls down slightly and settles to a level. Hold the tube vertical; the difference between level of mercury in tube and in the trough gives the atmospheric pressure in terms of mercury column (diagram 47 *b*). Atmospheric pressure acting on the surface of mercury in the bowl supports the *h* cm column of mercury in the tube. Above this column of mercury is vacuum which is called Torricellian vacuum.

It is advantageous to use mercury as a barometric material because it (*a*) is dense, so that a short column is necessary; (*b*) is silver in colour, so that it can be seen easily; (*c*) does not stick to glass, so that accurate reading can be taken; and (*d*) forms very little vapour, so that the vacuum is almost true and the reading is accurate.

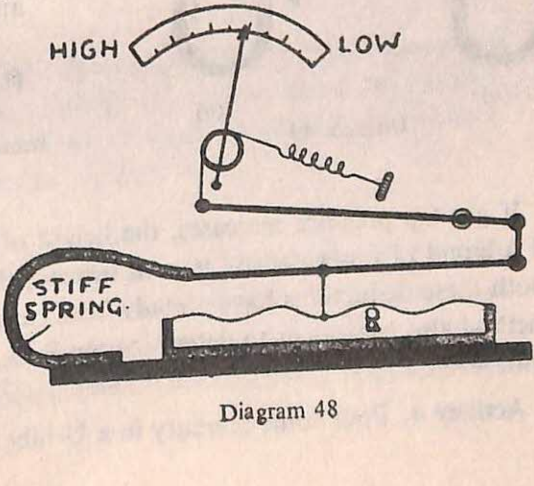


Diagram 48

ANEROID BAROMETER

Mercury barometers are bulky and quite inconvenient to carry around. The most common type of barometer

is the ***aneroid barometer***, so called because it contains no liquid. Essentially, it consists of a box *B* which is partially evacuated (diagram 48). The top of this box is made of a thin metal so that it is sensitive to small changes in pressure. This small movement of the top of the box is "magnified" by a series of levers and causes the pointer to move along a circular scale. The scale is graduated with a good mercury barometer. The scale is usually marked stormy, fair, etc. because change of atmospheric pressure causes such changes in the weather.

Aneroid barometers are also used as altimeters in aircrafts because increase of altitude is accompanied by decrease of atmospheric pressure; a fresh calibration of the scale is therefore sufficient to convert the instrument into an altimeter.

R.D. OF LIQUIDS BY U-TUBE

Pressure in liquids is actually due to weight of liquid column acting on a specified area. This explains why unequal pressures acting on a liquid in two limbs of a U-tube create unequal levels. Consider a U-tube containing mercury. When both limbs are open to the atmosphere, pressures are equal on its two surfaces and the two levels are equal.

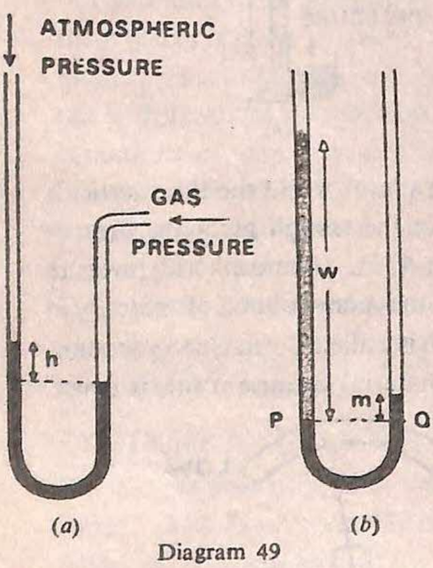


Diagram 49

Let us connect one end to the gas tap which creates a difference h in the two levels (diagram 49 *a*). We say that the gas tap pressure is h cm in excess of atmospheric pressure. If mercury has density d g/cm^3 and area of cross-section of the tube is A cm^2, then

Volume of h cm column of mercury
$$= A \times h \text{ cm}^3$$
Hence, Mass of h cm column of mercury
$$= A \times h \times d \text{ gram}$$
and weight of h cm column of mercury
$$= A \times h \times d \text{ g-f}$$
Hence, pressure due to h cm column of
$$\text{mercury} = \frac{A \times h \times d \text{ (g-f)}}{A \text{ (cm}^2)}$$
$$= h \times d \text{ g-f/cm}^2$$

If gas tap pressure increases, the height of mercury column will also show a rise. If a liquid of lesser density is used instead, the liquid column will have to be more. Both these deductions have already been experimentally verified by us earlier. This method also enables us to determine the R.D. of a liquid, epecially if it does not mix with water.

Activity 4. Pour some mercury in a U-tube. Next pour water through one limb till

the limb is almost full. The water column will push down the mercury in that limb and there will be a resultant rise in the other limb (diagram 49 *b*). Consider the common level of mercury *PQ*. From earlier experiments it is obvious that the pressure due to water column *w* cm on the mercury surface at *P* is equal to the pressure due to mercury column *m* on the common level *Q*. If density of water is *W* and that of mercury is taken as *M*, in g/cm^3 units,

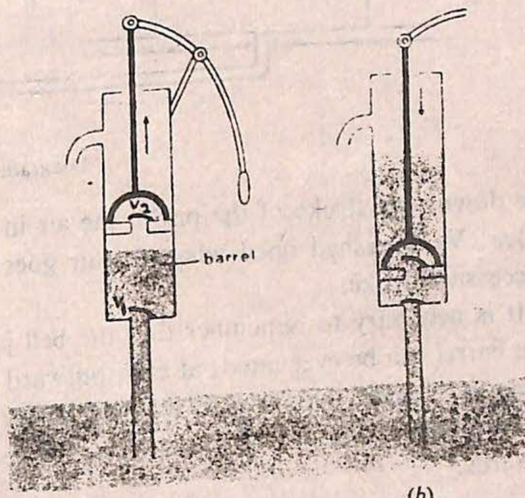
Then, pressure of water column w = pressure of mercury column m

Or $w \times W$ (g-f/cm^2) = $m \times M$ (g-f/cm^2)

Hence, R.D. of mercury (in relation to water) $= \dfrac{M}{W} = \dfrac{w}{m}$

THE LIFT PUMP

This mechanical device is used to raise liquids to higher levels. It consists of a cylinder with a tight-fit piston and a handle; the bottom of the cylinder ends in a long tube which is immersed in the liquid. The two valves V_1 and V_2 open upwards. In the upward stroke of the piston, a partial vacuum is created inside the barrel; hence V_2 is closed by greater pressure from top. V_1 is pushed open as air, followed by liquid, enters the barrel due to atmospheric pressure acting on the liquid level outside the tube (diagram 50 *a*).



(*a*) (*b*)

Diagram 50

In the downward stroke the pressure in barrel is raised which pushes V_1 and closes it; the V_2 valve is pushed open when air and then liquid comes out on top of the piston (diagram 50 *b*). In the next upward stroke the air and liquid come out of the outlet tube while the previous process in barrel is repeated.

A lift pump is used where water is to be raised upto a height of about 10 m, which is the column of water the normal atmosphere can support.

THE EXHAUST OR SUCTION PUMP

The exhaust pump is similar in construction to the lift pump. It consists of a cylinder fitted with an air-tight piston and a handle. The valve V_2 which opens outwards is fitted to the piston while valve V_1 is fitted where the cylinder is joined to the tube; the tube connects to a metal plate over which is placed the chamber, such as a bell jar, to be evacuated (diagram 51).

During an outward stroke of the piston, partial vacuum is created in the barrel which closes valve V_2 and opens valve V_1 when air from the bell jar enters the barrel. In

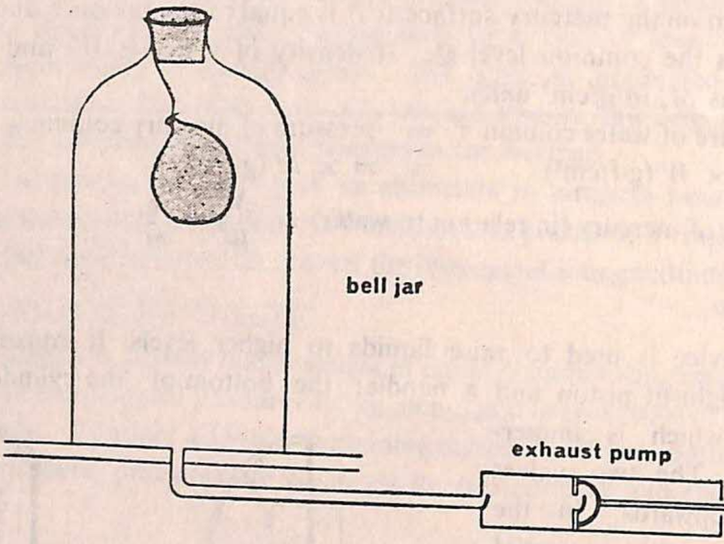


Diagram 51

the downward stroke of the piston the air in barrel is compressed which closes V_1; valve V_2 is pushed open when the air goes out. This process is repeated at each successive stroke.

It is necessary to remember that the bell jar can be evacuated only to the extent the barrel can be evacuated; at each outward stroke the air in barrel must have lower pressure created than that in the bell jar. Vacuum grease is applied at all places such as between piston and barrel, and between jar and plate, so that no air escapes inwards.

BICYCLE PUMP

The bicycle pump is used to transfer air from the atmosphere into the tyre of a bicycle; its valves are therefore fitted to open inwards. The pump actually contains only one valve V_2 fitted to the piston while the other valve V_1 is fitted on to the bicycle tube. Valve V_2 is a cup-shaped leather washer while V_1 is a small piece of rubber tube which fits tightly on a metal tube *B* having a hole *C* (diagram 52 *a*).

When the piston is raised the opening *C* is closed; thus, no air from the tyre enters the barrel which has reduced pressure. Air from the atmosphere forces the leather washer to enter the barrel. When the piston is lowered, pressure of air inside the barrel is raised; this presses the sides of washer tightly against the walls of the barrel and closes it. The compressed air opens the valve tube V_1 and air enters the tyre.

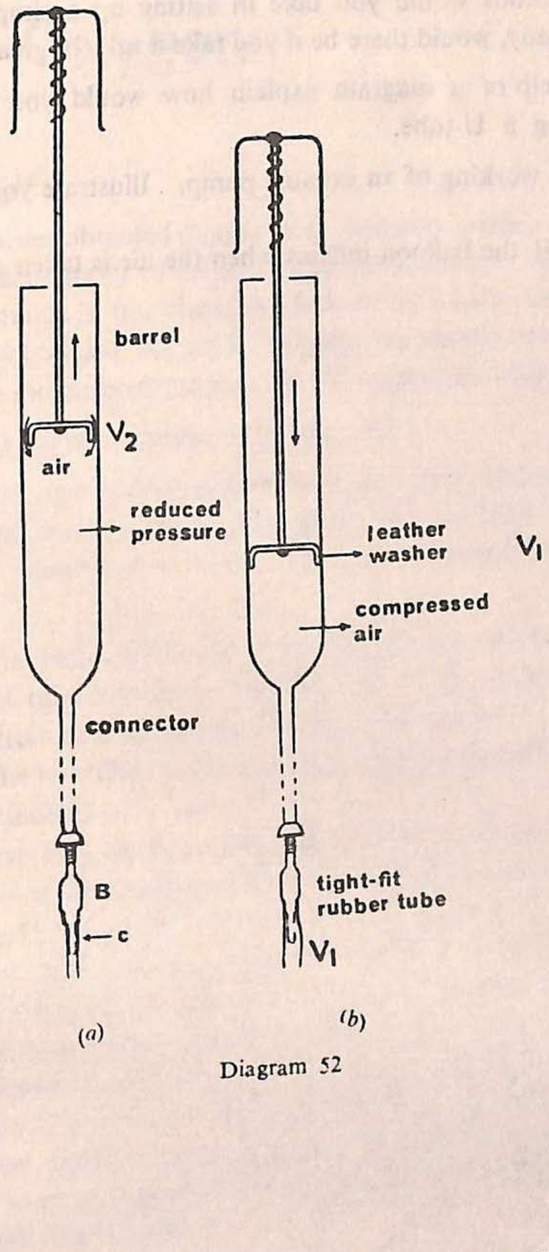


Diagram 52

PROBLEMS

1. Calculate the difference of pressure exerted by a column of mercury 75 cm high and a column of water 10 metre high. Given that R.D. of water is 1, while R.D. of mercury is 13.5.
2. Why is water not suitable for use in barometers? Which properties of mercury make it more suitable for use in barometers?

3. What precautions would you take in setting up a simple barometer? What difference if any, would there be if you take a tube of greater diameter?
4. With the help of a diagram explain how would you find out the R.D. of alcohol using a U-tube.
5. Describe the working of an exhaust pump. Illustrate your answer with a clear diagram.
   In diagram 51 the balloon inflates when the air is taken out. Why?

7 Oxygen

Priestley and Lavoisier obtained oxygen from mercury oxide. This is an expensive compound and the quantity of oxygen obtained from it is rather small. You will find several compounds in the chemistry laboratory which contain oxygen, but only a few methods of obtaining the gas from them are simple or cheap. We shall now study some of the methods of preparation of oxygen, its properties and uses.

OXYGEN FROM POTASSIUM CHLORATE

Potassium chlorate and hydrogen peroxide are two compounds which contain oxygen. By simple heating these compounds give up their oxygen. While doing experiments note whether gentle or strong or prolonged heating is necessary to produce the gas.

Activity 1. Potassium chlorate is a white crystalline substance; take it in a clean dry hard-glass test tube and heat. The crystals of this compound will change to a liquid state. Introduce a glowing splint into the test tube. Does the splint glow brightly? Heat the test tube until it is red-hot and again introduce the glowing splint. Is the splint rekindled?

You will observe that the splint is rekindled only when the compound is strongly heated. Now mix some manganese dioxide with potassium chlorate (1 part of manganese dioxide to 4 parts of potassium chlorate is suitable) and heat gently in a clean, dry hard-glass test tube. What happens when the glowing splint is introduced into the test tube? Is there any change in the colour of the mixture after heating?

By the addition of some manganese dioxide, a black substance, even gentle heating of potassium chlorate in the test tube rekindles the glowing splint. The experiment shows that oxygen is given off from a mixture of potassium chlorate and manganese dioxide at a lower temperature than if potassium chlorate alone were heated. In fact, if you heat some manganese dioxide alone in a hard-glass test tube until it is red-hot, no oxygen is given off.

PREPARATION OF OXYGEN IN THE LABORATORY

Activity 2. The method of heating a mixture of potassium chlorate and manganese dioxide can be used for the preparation of oxygen in the laboratory. The experiment should be conducted carefully; it can be dangerous if heating is not done gently and cautiously.

Mix thoroughly about 4 g of manganese dioxide and 16 g of potassium chlorate in a mortar. Place the mixture in a hard-glass tube and fit up the apparatus as shown in diagram 53. Heat the test tube gently for about two minutes and then put a gas jar filled with water over the ***bee-hive shelf.*** The gas jar is filled to the brim with water, covered with a well-greased lid, and lowered upside down into the trough containing water before the lid is removed. There should be no air bubbles inside the water-filled jar.

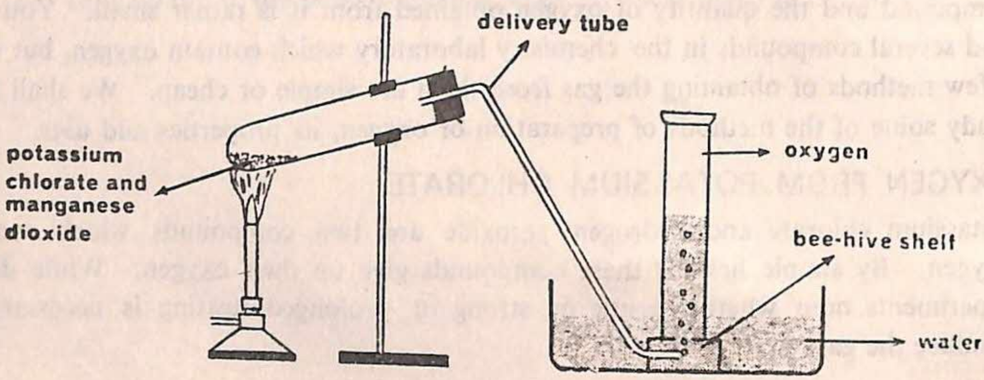


Diagram 53

Continue heating and you will see the bubbles of oxygen gas rising up, and displacing the water in the gas jar. This method of collecting a gas is by downward displacement of water. Why is the gas jar not placed on the bee-hive shelf before heating the mixture?

When the mixture is heated, the air inside the test tube is displaced first before oxygen starts coming out. When the water in the jar is completely displaced by oxygen, cover it with a well-greased lid beneath the water level in the trough and remove it. Fill several such gas jars with oxygen. The end of the delivery tube should be removed from the trough before the heating is stopped. Why?

When heating is stopped, the pressure of gas inside the test tube would become less due to cooling, and water would enter the test tube if the end of the delivery tube were allowed to remain in water.

When a glowing splint is introduced into one of the jars, the splint bursts into flame. This is a good method of identifying oxygen gas. Is the gas prepared by this method pure? Does it have any colour and odour?

You will find that the gas jars containing oxygen are misty; this is due to the water vapour present along with oxygen.

CATALYST

Does the manganese dioxide in the above mixture change into another substance when heated?

Activity 3. Mix about 5 g of manganese dioxide with about 20 g of potassium chlorate and heat gently in a hard-glass test tube. Continue heating gently for about 10 minutes and test for the oxygen gas coming out. Allow the test tube to cool and add about 15 cm^3 of distilled water. Shake well and filter the contents through a filter paper which has been weighed before.

You will notice that a black powder is left on the filter paper. Wash the black powder four or five times on the filter paper with distilled water. Remove the filter paper and dry it in an oven or by exposing it to the sun. When fully dry, weigh the filter paper again with the black residue. The difference in the two weights will give you the weight of the black residue.

You will find that the mass of the residue is the same as that of manganese dioxide taken originally; its colour is also the same. If the residue is added to about 1 cm^3 of concentrated hydrochloric acid and heated, the greenish-yellow chlorine gas is given off which turns a moist litmus paper colourless. This experiment shows that the manganese dioxide, which is the black residue left on the filter paper, has not changed chemically.

The purpose of manganese dioxide in the above experiment was therefore to speed up the reaction; several other substances are used for this purpose about which you will study later on. There are also other substances which decrease the rate of reaction. All such substances are called ***catalysts. A catalyst is a substance which changes the speed of a chemical reaction, but itself remains unchanged chemically.*** Since there is no change in the mass of a catalyst, it is usually effective in small quantities.

Actually, in this experiment potassium chlorate decomposes to form potassium chloride. This chemical change could be written as follows:

potassium chlorate ⟶ potassium chloride + oxygen

OXYGEN FROM HYDROGEN PEROXIDE

Activity 4. Place about 2 g of manganese dioxide in a test tube and add about 5 cm^3 of a solution of hydrogen peroxide. What do you observe in the test tube? What happens to a glowing splint introduced immediately in the tube?

You will notice that a brisk effervescence takes place inside the test tube and oxygen is evolved. This reaction is a more convenient method of preparing oxygen in the laboratory. No heating is required and the method is absolutely safe. Manganese dioxide acts as a catalyst in this reaction. Hydrogen peroxide decomposes into water and oxygen.

hydrogen peroxide ⟶ water + oxygen

Activity 5. To collect oxygen by downward displacement of water, the apparatus is set up as shown in diagram 54. Put about 10 g of manganese dioxide in a flat-bottomed conical flask which is fitted with a two-holed rubber stopper. The stopper

carries a dropping funnel and a bent delivery tube. Open the tap of the dropping funnel gradually, when small quantities of hydrogen peroxide solution will fall on to the manganese dioxide. After an interval of about a minute, put a gas jar filled with water on the bee-hive shelf.

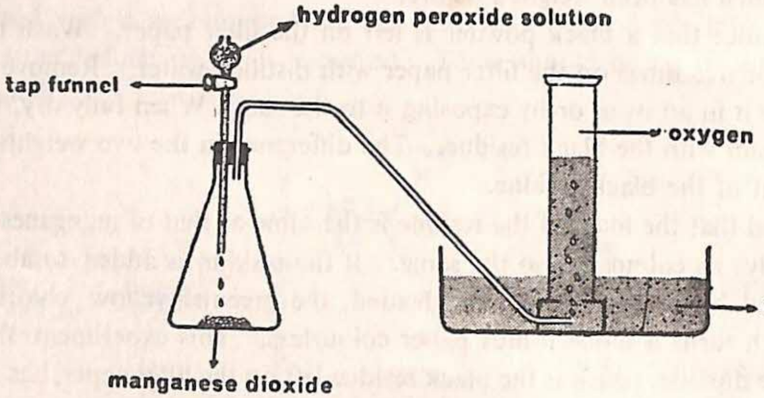


Diagram 54

When the gas jar is filled with oxygen by displacing water, cover it with a well-greased glass lid beneath the water and remove from the trough. You can collect some more jars of oxygen this way. How can you control the production of oxygen gas in this method? Is the oxygen collected pure?

As each drop of hydrogen peroxide solution falls on to the manganese dioxide, there is evolved at once a small quantity of oxygen. Hence the evolution of oxygen can be controlled by the tap of the dropping funnel. In this experiment also the oxygen contains water vapour.

PROPERTIES OF OXYGEN

The properties of oxygen can be investigated by carrying out the following experiments on the gas collected in the gas jar:

(*a*) Note the colour and smell of the gas.

(*b*) Is the gas soluble in water?

(*c*) Add two or three drops of solutions of blue and red litmus in two separate jars and notice any change in the colour of the solutions.

(*d*) Place a piece of dry phosphorous into a deflagrating spoon and warm gently; then lower the spoon into a jar containing oxygen and observe the burning of phosphorous (diagram 55). Is there any difference in the burning of phosphorus in air and in oxygen?

Put a little water into the gas jar, shake and add two drops of blue litmus to the solution. Do you notice any change of colour now?

(*e*) Hold a piece of magnesium ribbon with a pair of tongs. Burn it in a bunsen

flame and immediately introduce the burning ribbon into a jar of oxygen. What difference do you observe in the burning of magnesium in air and in oxygen? What happens when the residue is added to water, warmed and a drop or two of red litmus solution is added to it?

You will note that oxygen is a colourless and odourless gas. If the gas were easily soluble in water, it could not have been collected by displacement of water in the laboratory preparation. Oxygen is, however, slightly soluble in water and living organisms in water depend on it. Litmus solutions do not change their colour when coming in contact with oxygen; hence the gas is ***neutral.***

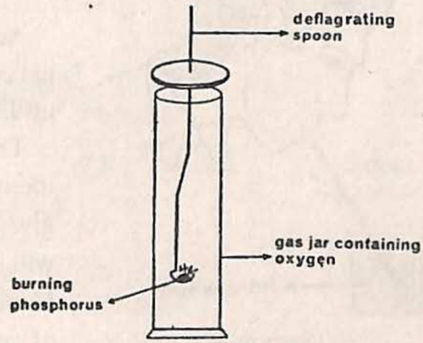


Diagram 55

Phosphorus burns brightly with a dazzling yellow flame and produces dense fumes of phosphorus pentoxide. The intensity of burning is greater in oxygen than in air. Oxygen is the gas which supports the burning of substances and this property is diluted because of the presence of nitrogen in air. The burning of phosphorus is written as follows:

phosphorus + ***oxygen*** ⟶ ***phosphorus pentoxide***

Magnesium also burns with a blinding white light in oxygen and produces dense white fumes of magnesium oxide.

magnesium + ***oxygen*** ⟶ ***magnesium oxide***

Other elements also combine with oxygen to form their oxides. A lot of heat energy is given out when substances burn in oxygen.

You will notice that when solutions of oxides of various substances are tested with litmus, those of non-metals change blue litmus red and those of metals change red litmus blue. Non-metallic oxides are called ***acidic oxides*** because of the ***acidic solutions*** produced when they are dissolved in water. Metallic oxides are called ***basic oxides*** and produce ***basic solutions*** when they are dissolved in water. These solutions are classified on the basis of their action on litmus.

OXIDATION AND REDUCTION

A reaction in which oxygen combines with another substance is called oxidation. The substance which combines with oxygen is said to be ***oxidised.*** Magnesium, for example, is said to be oxidised when it combines with oxygen. Burning in air or in oxygen is an oxidation reaction.

A reaction in which oxygen is removed from another substance is called reduction. The substance which loses oxygen is said to be ***reduced.*** For example, when mercury oxide is heated, it loses oxygen and is said to be reduced. Oxidation and reduction have wider meanings which you will study later on.

RESPIRATION AND OXIDATION

In respiration, air is breathed into the lungs, when a portion of the air enters the blood. A part of this air reacts with the digested food and the waste gases pass from the blood stream to the lungs from where it is breathed out. Is there any difference between inhaled air and exhaled gases?

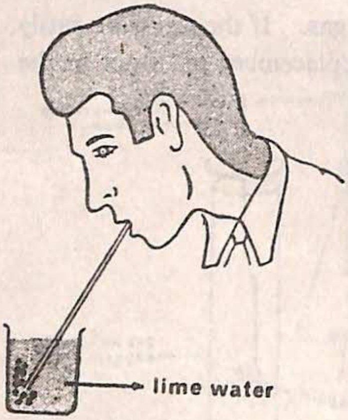


Diagram 56

Activity 6. Blow the exhaled air through a clean glass tubing into lime water. Observe what happens and explain (diagram 56).

The lime water turns milky. This is a method of identifying carbon dioxide gas. This experiment is given in greater detail in the first book. Ordinary air will take a very long time to turn lime water milky. Hence, exhaled gases contain a much greater proportion of carbon dioxide than present in ordinary air.

A small portion (about 4 per cent) of the air we breathe in is used up to oxidise the food. The oxidation of food produces heat energy which keeps our body warm and which is helpful in keeping us active. The energy liberated in the oxidation of food does not, however, produce high temperatures and light which are associated with burning. The exhaled gases contain about 16 per cent of oxygen as compared to 21 per cent present in ordinary air.

LARGE SCALE PREPARATION OF OXYGEN

Oxygen has vast applications in everyday life. It is required in very large quantities by industries. The cost of production is, therefore, a very important consideration while preparing a substance on a large scale. The laboratory preparation methods described above, in which certain compounds are heated to obtain oxygen, are not cheap for obtaining large quantities of the gas. Which is the most abundant source of supply of oxygen?

Air is obviously the cheapest and the most abundant source of oxygen. The problem is to separate oxygen from the mixture of gases present in air. What happens when gases are cooled? What happens when a mixture of liquids is subjected to fractional distillation? Can you suggest a method of obtaining oxygen from air employing these two techniques?

If air is changed into liquid air, we could obtain oxygen by fractional distillation of the liquid air. To change air into a liquid needs intense cooling; this cannot be done in the school laboratory. Allow compressed air to suddenly come out of an inflated bicycle tube and put your finger over the end of the valve. You will feel a cooling effect. The same principle is applied to change air into liquid air.

In the commercial preparation of oxygen, air free from carbon dioxide and water vapour is compressed, cooled and suddenly allowed to expand several times. Finally, the air is cooled to about $-200°C$ when it changes into liquid air. The liquid air is allowed to evaporate slowly when nitrogen, which has a boiling point of $-196°C$, escapes out as gas leaving liquid oxygen (boiling point $-183°C$). The liquid oxygen is then filled into strong steel cylinders. Diagram 57 gives an idea of how oxygen is obtained from air while, at the same time, nitrogen is also obtained on a large scale.

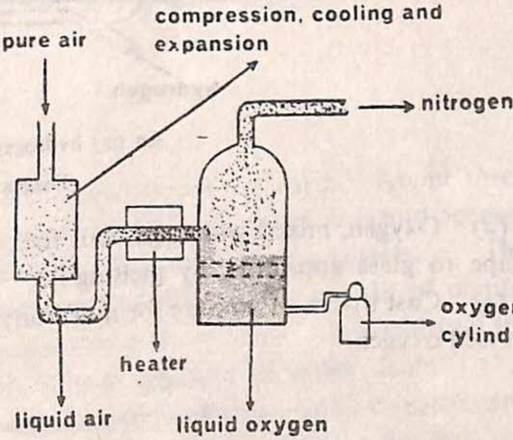


Diagram 57

USES OF OXYGEN

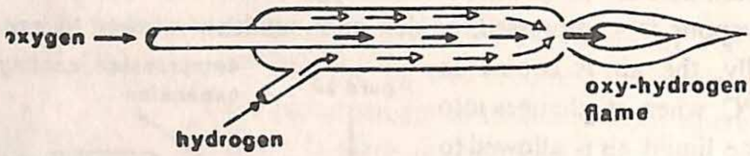
The use of any substance depends upon its properties. In the study of some of the properties of oxygen, therefore, a reference has already been made of its uses.

(a) In breathing. Oxygen present in air is a supporter of life. By oxidising food, it produces heat energy which keeps our body warm and enables us to do work. Patients in hospitals suffering from certain diseases of the lungs are provided increased proportion of oxygen from oxygen cylinders. At high altitudes the air becomes rarefied and the supply of oxygen is not adequate; men going on high mountain expeditions and for high altitude flying a supply of oxygen from cylinders becomes necessary. Fishes breathe in the oxygen dissolved in water while deep-sea divers carry oxygen equipment with them.

It would be well worth remembering that too much supply of oxygen would increase the rate of energy production which may be harmful to a living organism. A fish adjusted to breathing the small quantity of dissolved oxygen from water would soon die when kept in the open air. You can experiment with a small living organism adjusted to normal air, such as a cockroach, by placing it in a jar of oxygen; it will feel as uneasy as a fish out of water and will die quickly.

(b) High temperature flames. A mixture of oxygen and hydrogen burns producing a very hot flame at a temperature of about 2000°C. A flame produced by the burning of a mixture of oxygen and acetylene has a temperature of about 3300°C. These flames can be used for cutting and welding of metals.

(c) Fuel. Liquid oxygen is used in rockets to make the burning of fuel more vigorous. Liquid oxygen is preferred to gaseous oxygen because it has much less volume (greater density) for the same mass of oxygen.



An oxy-hydrogen flame torch

Diagram 58

(*d*) Oxygen, mixed with a gaseous fuel, produces a flame which is used for giving shape to glass apparatus by melting it.

(*e*) Cast iron is an impure form of iron; it can be changed into steel by using compressed oxygen.

PROBLEMS

1. Explain with a diagram a method of preparation of oxygen in the laboratory. Why is the gas collected in gas jars after a few minutes of heating? Is the oxygen collected pure?
2. What is a catalyst? How will you show that manganese dioxide acts as a catalyst in the preparation of oxygen from hydrogen peroxide?
3. What do you understand by the terms oxidation and reduction? Give one example of each reaction.
4. When hydrogen is passed over heated copper oxide, the products are water and copper metal. Explain how one substance is oxidised while the other is reduced. Is respiration an oxidation or a reduction reaction? Explain.
5. Taking the example of one metal and one non-metal, describe how each burns in oxygen. State the reaction to the litmus solution of their products in water.
6. How is oxygen manufactured on a large scale? What other important gas is obtained in this process? Mention some important uses of oxygen.
7. What are the different types of oxides? What type of oxides are the following: calcium oxide, sulphur dioxide, barium oxide, nitrogen dioxide, water?

8 Water and Hydrogen

Water is the most abundant and widely distributed liquid on earth. About three quarters of the earth's surface is covered by water of the lakes, rivers, seas and oceans. Water is present as vapour in the air and as clouds in the upper atmosphere. The soil contains large quantities of water which are essential for the growth of plants. Without water, all human beings and animals would die of thirst. It is essential for cooking and washing. Our food contains a large quantity of water: from 3 to 4 per cent in dry cereals such as maize and wheat, to about 90 per cent in tomatoes and fresh green vegetables. Milk contains roughly 88 per cent of water. In fact, our body contains about 65 % of water. Life without water is impossible to imagine.

THE WATER CYCLE

The circulation of water from the earth's surface to the sky and back to the earth is called the ***water cycle***. Water is constantly leaving all exposed surfaces on the earth such as the oceans and the rivers, the land and the human skin. This largely happens by evaporation due to the heat energy from the sun. Plants give out large amount of water vapour during transpiration. This water vapour returns to the earth in the form of rain, snow and hail.

The air is a great storehouse of water vapour. In times of drought, the water vapour has been changed into artificial rain in some experiments.

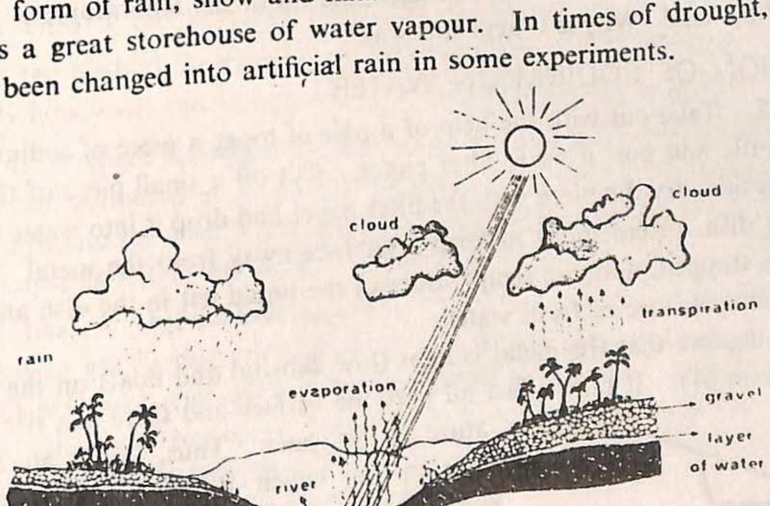


Diagram 59

Part of the rain water sinks deep into the earth's crust and penetrates the soil till it reaches a layer of an impervious rock such as clay. This water appears as a spring or may be brought to the surface when a well is sunk.

Activity 1. Put two drops each of rain water, spring or well water, river water and sea water, if available, on separate microscope slides. Evaporate the samples of water to dryness by putting the slides in the sun. Now observe under a microscope the residue left on the glass slides. How do the amounts of residue left behind compare?

You will notice that rain water leaves hardly any residue while sea water leaves the maximum amount (diagram 60) Rain water contains no dissolved substances and is almost as pure as distilled water. As the rain water flows through various layers of rocks and the soil, it dissolves various chemicals until it goes into the sea; water is an excellent solvent and all the dissolved substances form the residue (in sea water) in the above experiment. River water may contain living bacteria, some of which cause dangerous diseases such as typhoid and cholera.

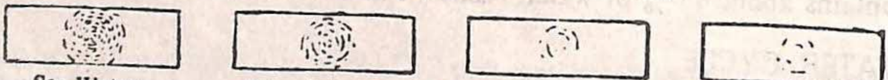


Diagram 60

Pure water freezes at a fixed temperature, 0°C, which we call the lower fixed point, and boils at another fixed temperature, 100°C, which is called the upper fixed point.

Sodium is a metal which is kept in kerosene oil in the laboratory; it should not be touched by hand. Why is it kept this way?

THE ACTION OF SODIUM ON WATER

Activity 2. Take out with the help of a pair of tongs a piece of sodium from the kerosene bottle and put it on a filter paper. Cut off a small piece of the metal of about 2 mm side, dry the piece with the filter paper and drop it into water taken in an evaporating dish. Remember to keep your face away from the metal. When the reaction has stopped, note the temperature of the liquid left in the dish and compare it with the temperature of fresh water.

You will observe that the metal is light (low density) and floats on the surface of water (diagram 61). It moves fast all over the surface and there is a rise in temperature of the water. Thus, this is an exothermic reaction in which heat energy released. The metal changes into a silvery ball which disappears after sometime. There is a brisk *effervescence* showing that a gas is produced; in semi-dark

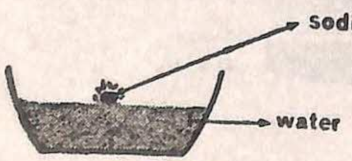


Diagram 61

condition, you may also see sparks of yellow colour. Take in a test tube about 2 cm^3 of the liquid in the dish and add to it a drop of red litmus. The red litmus turns blue showing that a basic solution is formed by the action of sodium on water.

It is obvious why sodium is kept in kerosene oil; the water vapour present in the air would react with it. Even the moisture of our hands can react with the metal. It is therefore not touched by hand.

Activity 3. Wrap a small piece of dry sodium in a small piece of dry iron wire gauze. Drop it into a dish containing water and immediately cover it with an inverted test tube full of water. Bubbles of a gas will be noticed rising up into the test tube and the gas is collected by displacing the water (diagram 62).

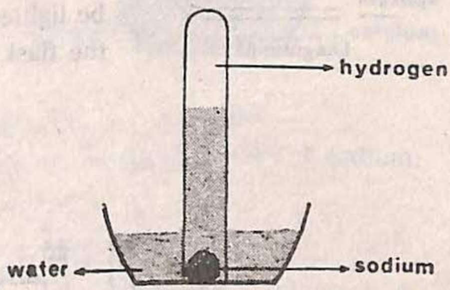


Diagram 62

Close the test tube mouth with your thumb under the surface of water and remove it from the dish. Introduce a burning splint into the test tube; the gas burns with a 'pop' sound. What could be this gas and how was it formed?

The gas produced is hydrogen. It could not have come from sodium which is an element. The gas has come from water which is a compound of hydrogen; the basic solution left behind is a solution of a compound of sodium. The basic solution is called sodium hydroxide. The reaction can be written as:

sodium + water ⟶ sodium hydroxide + hydrogen

THE SYNTHESIS OF WATER

Synthesis is the method of preparing a complex substance from simpler substances. Let us study how water can be prepared from two elements, hydrogen and oxygen.

Activity 4. Prepare hydrogen gas by the action of dilute hydrochloric acid on zinc. The acid is poured in a flask containing zinc through a thistle funnel until its lower end dips into the acid. The gas comes out of a delivery tube while a solution of zinc chloride is left in the flask.

zinc + hydrochloric acid ⟶ zinc chloride + hydrogen

The hydrogen gas evolved contains water vapour which is removed by passing the gas through a U-tube containing ***anhydrous*** calcium chloride. Anhydrous calcium chloride is called a ***drying agent*** because it removes water vapour from other substances. Since hydrogen gas is less dense than air, it is collected by downward displacement of air in a test tube (diagram 63).

Collect a sample of the hydrogen in a test tube and introduce a lighted splint. The gas burns with a loud sound. A mixture of air and hydrogen forms an

explosive mixture. Continue to take samples of hydrogen in a test tube and light the gas until it burns quietly. This indicates that the air has been swept away from the apparatus.

Now light the gas at the mouth of a jet. Allow the flame to play on the cold surface of a glass retort through which a stream of water continuously flows (diagram 64). Remember that the hydrogen should not be lighted at the jet before all the air is displaced from the flask.

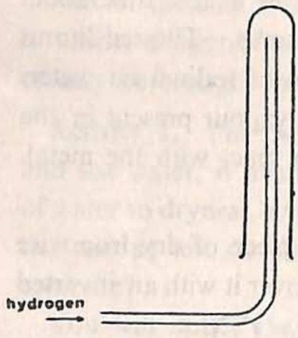


Diagram 63

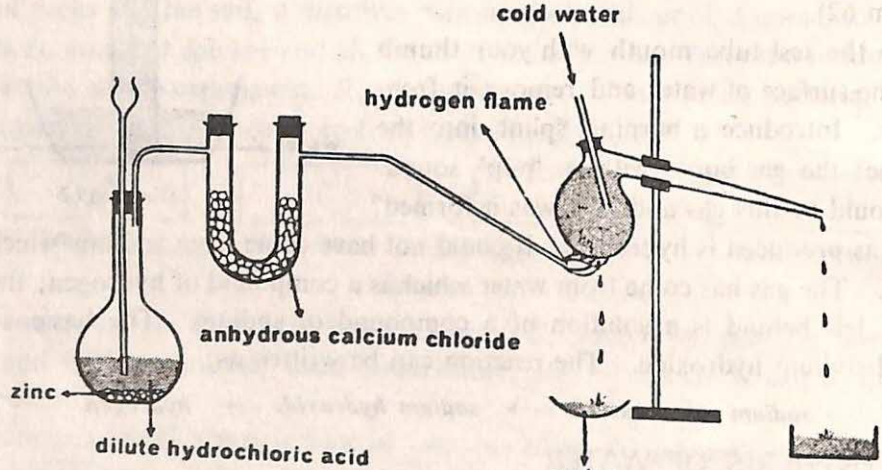


Diagram 64

You will observe that a colourless liquid is formed on the retort; collect the liquid in a watch glass. Test the liquid with cobalt chloride paper. The cobalt chloride paper turns pink showing that water has been produced by the burning of hydrogen in air. If a sufficient amount of this liquid is collected, it boils at 100°C under normal atmospheric pressure. This liquid formed is pure water.

When elements burn in air, they combine with oxygen of the air to form their oxides. Hydrogen therefore combines with oxygen to form its oxide which is water; water is hydrogen oxide.

hydrogen + *oxygen* ⟶ *water*

REACTION OF WATER ON CALCIUM

Activity 5. Drop a piece of calcium, a grey metal, into a dish containing water.

Unlike sodium, the metal sinks at the bottom as it is denser than water. You will notice effervescence taking place. Invert a test tube full of water over the metal. Bubbles of gas rise and get collected by displacing the water (diagram 65). When all the water has been displaced, close the open end of the test tube with your finger and remove it from the dish.

Now introduce a burning splint into the test tube. The gas burns with a 'pop' showing that the gas is hydrogen. The solution left in the dish turns red litmus blue showing that it is basic. The reaction can be written as follows:

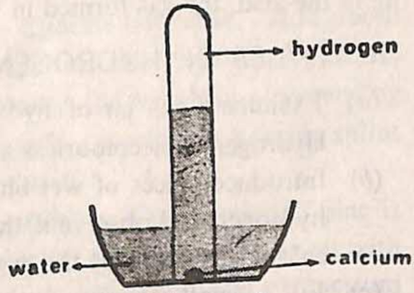


Diagram 65

calcium + *water* ⟶ *calcium hydroxide* + *hydrogen*

The reaction of calcium with water is much slower as compared to that of sodium. This shows that different metals have different ***reactivity***.

PREPARATION OF HYDROGEN IN THE LABORATORY

A convenient method for the preparation of the gas in laboratory is by the action of dilute hydrochloric acid on zinc.

Activity 6. Take a few pieces of zinc into a flat-bottomed flask and pour dilute hydrochloric acid down a thistle funnel until the end of the funnel is dipping in the acid. Can you tell why?

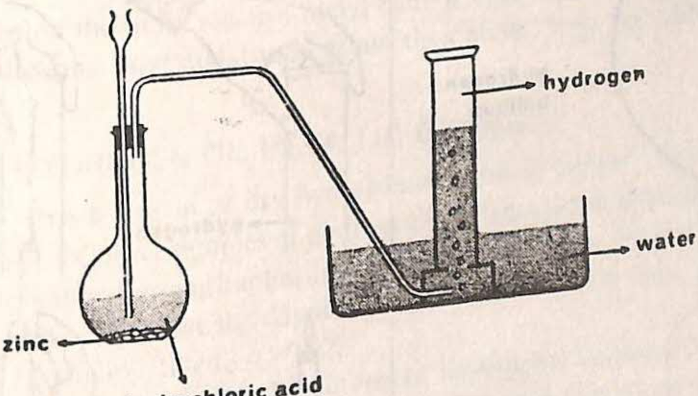


Diagram 66

A brisk effervescence indicates the formation of hydrogen. After the first few bubbles are allowed to escape, collect the gas over a bee-hive shelf by the downward displacement of water (diagram 66). Put a greased glass plate over the open end of the gas jar and remove it from the water. Is the gas collected pure?

In this way several gas jars can be filled. The hydrogen which comes out in the beginning contains air which is present in the flask. If the thistle funnel is not dipping in the acid, the gas formed in the flask will escape out through the funnel.

PROPERTIES OF HYDROGEN

(*a*) Examine a gas jar of hydrogen and find out the colour and odour of the gas. Hydrogen is a colourless and odourless gas.

(*b*) Introduce pieces of wet blue and red litmus papers into two separate jars of hydrogen and observe if there is any change in colour. There is no change in colour showing that the gas is neutral.

(*c*) Fill a small amount of dilute hydrohloric acid in a bottle and drop in a few small pieces of zinc. After a while, fit a balloon on the mouth of the bottle (diagram 67). When the balloon is inflated, tie it with a string and remove from the bottle. If you release the balloon, it rises up showing that the gas is less dense than air.

(*d*) Hold a gas jar filled with hydrogen with its mouth downwards. Hold a lighted candle and bring the flame inside the mouth of the jar. The lighted candle is extinguished and the gas burns with a 'pop' sound at the mouth of the jar. Hydrogen is a flammable gas but does not support combustion; in the absence of oxygen, hydrogen will not burn (diagram 68).

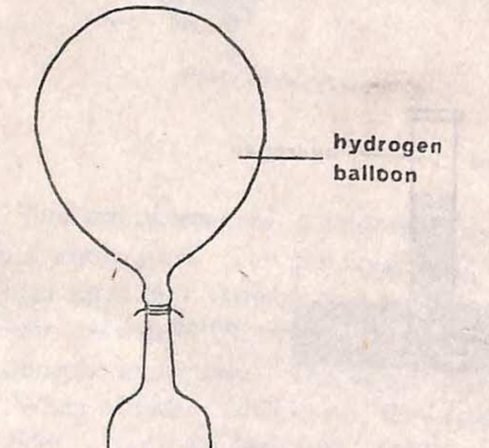


Diagram 67

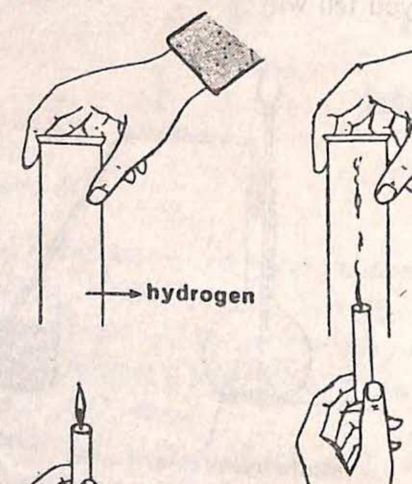


Diagram 68

REACTIVITY OF METALS

Activity 7. Take about 0.5 g of each of the four metals: magnesium ribbon, powdered zinc, iron dust and copper turnings in four separate test tubes. Add about 5 cm^3 of dilute hydrochloric acid to each of the metals and note the intensity of the reaction. Do all the metals react with the acid? Arrange the metals in a descending order of activity by observing their reaction with the acid. Introduce a burning splint into each of the test tubes and find out the gas produced.

You will notice that magnesium reacts most vigorously. The reaction of zinc is less vigorous while iron shows even less reactivity; copper does not react at all with dilute hydrochloric acid. The reaction of the acid on zinc, iron and magnesium produces hydrogen.

The metals are elements and do not themselves produce hydrogen; the hydrogen comes from the acid. In fact, you will study later that other acids also contain hydrogen.

Experiments such as the action of water and the action of hydrochloric acid on metals show the difference in the reactivity of metals. On the basis of such reactions, a list of metals called the ***activity series of metals*** can be prepared as shown below:

1. potassium	5. aluminium	9. lead	13. gold
2. sodium	6. zinc	10. copper	14. platinum
3. calcium	7. iron	11. mercury	
4. magnesium	8. tin	12. silver	

Potassium being the most reactive metal cannot occur free in nature. Gold and platinum are the most ***inert*** metals and retain their shine; they are therefore used in jewellery.

ACTION OF HYDROGEN ON METALLIC OXIDES·

Activity 8. Pass a stream of dry hydrogen over black copper oxide contained in a hard glass tube. Collect samples of hydrogen in a test tube at intervals and test the presence of air in it by burning a splint into the test tube. When the gas burns quietly, light it at the jet. Now heat the copper oxide from below; the tube containing the oxide should be slightly tilted. (Why?)

Remove the burner after about 20 minutes of heating but continue to pass the gas while the solid inside the tube is cooling. You will notice that drops of a colourless liquid at the lower end of the tube are formed which change cobalt chloride paper pink; hence, the liquid formed is water. The residue left in the tube is brown in colour and is the copper metal. It may therefore be concluded that hydrogen removes oxygen from copper oxide to form water and copper.

$$\textit{copper oxide} + \textit{hydrogen} \longrightarrow \textit{copper} + \textit{water}$$

In the above experiment the tube was kept slightly tilted to prevent the water from running back on to the hot part of the tube. The stream of hydrogen is passed as the copper is cooling to avoid air entering the tube which may oxidise the hot metal. If the experiment is repeated using yellow lead oxide, a similar result will be obtained; lead metal and water are formed.

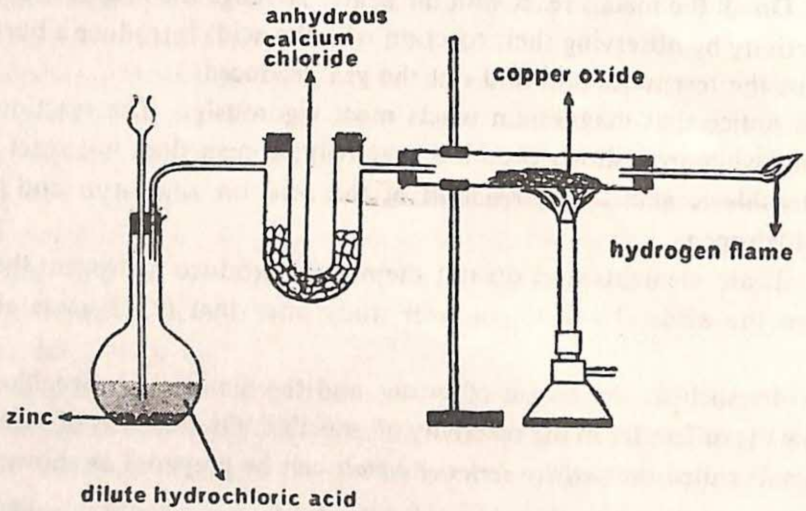


Diagram 69

When oxygen is removed from an oxide, the oxide is said to be reduced; the process is called reduction. Hydrogen, which has removed the oxygen, is called a ***reducing agent***. Reduction, like oxidation, involves some other changes also which we shall study later.

USES OF HYDROGEN

(*a*) One of the important uses of hydrogen is that in combination with nitrogen it forms ***ammonia*** which is the basis of many fertilisers. Fertilisers are extensively used in this country for crops to give a better yield.

(*b*) Hydrogen gas is used to convert liquid oils, such as groundnut and coconut oils, into solid fats. This process is called ***hydrogenation of oils*** and takes place in the presence of nickel as a catalyst.

(*c*) Oxy-hydrogen flames which have a temperature of about 2000°C are used for welding of metals.

PROBLEMS

1. Why is rain water considered the purest form of natural water? What is a water cycle in nature? What is its importance in our life?

2. How will you experimentally show that water is an oxide of hydrogen?
3. Using sodium and calcium how will you show that metals have different reactivity?
4. With the help of a clear and simple diagram explain how hydrogen gas can be prepared in the laboratory?
5. Show by an experiment, with a simple and clear diagram that hydrogen acts as a reducing agent.
6. Describe the reaction of sodium with water. What are the products formed?
7. What is a drying agent? On what consideration should a drying agent be selected for a particular gas?
8. How will you find out if a colourless liquid is pure water? How will you show the presence of water in a colourless liquid?

9 Acidic and Alkaline Solutions, and Salts

You may recall that non-metals combine with oxygen to form oxides; when the oxides are dissolved to form solutions, they turn blue litmus red. Such oxides are are called acidic oxides and the solutions are called ***acidic solutions.*** You will notice that some reagent bottles in the chemistry laboratory are labelled 'acids'. The acids commonly available are hydrochloric acid, sulphuric acid, nitric acid and acetic acid.

CONCENTRATED AND DILUTE ACIDS

Acids are available either as concentrated or as dilute acids. Concentrated acid is pure acid containing a little of water; dilute acid is pure acid containing more water than the acid. While preparing a dilute acid, the pure acid is slowly added to water; water should not be added to the pure acid. You should handle concentrated acids with great care; they produce blisters on the skin and burn holes in clothes. If some concentrated acid falls on the skin, it should be washed with plenty of water. The acids mentioned above are prepared by methods which are not simple and therefore are not described here.

BASIC SOLUTIONS

You may recall that metallic oxides, such as sodium and magnesium oxides, when dissolved in water turn red litmus blue. These oxides are called basic oxides and their solutions are called ***alkaline solutions.*** The oxides when dissolved in water form hydroxides as shown below:

sodium oxide + water ⟶ sodium hydroxide

calcium oxide + water ⟶ calcium hydroxide

Metallic oxides and hydroxides are usually called bases. A soluble base is called alkali.

The alkali commonly used in the laboratory are:

potassium hydroxide or caustic potash
sodium hydroxide or caustic soda
calcium hydroxide (slightly soluble in water and the solution called lime water)
ammonium hydroxide or ammonia solution

INDICATORS

You have been using litmus to find out if a solution is acidic or alkaline. Litmus is

a compound which is extracted from plants called lichens. Its colour is either red or blue. A paper soaked in litmus solution and dried is called a litmus paper. ***Substances such as litmus which change colour when treated with acidic or alkaline solutions are called indicators.*** Solutions which are neither acidic nor alkaline are called ***neutral solutions.*** Many other substances are also used as indicators.

Activity 1. Take about 2 cm^3 each of dilute hydrochloric acid and sodium hydroxide solution separately in two test tubes and add one drop of ***methyl orange*** solution to each of the solutions. Note the colour of the indicator in the two solutions. Now add one drop of an indicator, ***phenolphthalein,*** to each of the two solutions taken again in two separate test tubes and note the change in the colour of the indicator.

You will notice that methyl orange is a neutral solution; it turns red in an acidic solution and yellow in an alkali solution. Phenolphthalein is a colourless indicator in a neutral solution and remains colourless in an acidic solution; it turns pink in an alkaline solution. These indicators are complex substances; some indicators can be prepared from coloured substances available in our surroundings.

Activity 2. Mix 20 cm^3 of alcohol to the same volume of distilled water. Grind a few petals of a brightly coloured flower with about 10 cm^3 of the mixture in a a mortar with a pestle. Decant the coloured extract into a test tube and now add two drops of dilute hydrochloric acid; see if there is any colour of the extract. To the same test tube add a few drops of sodium hydroxide solution and see if a different colour is obtained. Repeat the experiment by preparing coloured extract of other flowers in the mixture of alcohol and water, and record the changes in colour in acidic and alkaline solutions.

You will notice that some of these coloured extracts give different colours in acidic and alkaline solutions and therefore could be used as indicators. Purple ***bougainvillea*** gives good results. You may also find out that in the preparation of the coloured extract some gentle warming is helpful.

CHARACTERISTICS OF ACIDIC SOLUTIONS

Activity 3. Prepare a very dilute solution of hydrochloric acid and put one drop of the acid solution on the tip of your tongue, What sort of taste does the solution have?

All acids have a sour taste. Many fruits have a sour taste because of the acid they contain. Lemon and citrus fruits contain citric acid, grapes contain tartaric acid while vinegar contains acetic acid. You can cut open a lemon or an orange and test the presence of an acid with the help of a blue litmus paper.

Activity 4. Take about 5 cm^3 each of dilute hydrochloric acid, dilute acetic acid and suplhuric acid separately in different test tubes and add a piece of magnesium

ribbon to each of the solutions. Test for any hydrogen evolved. Now put one drop of the solutions left after any reaction in the test tubes on different microscope slides. Evaporate the liquids by holding the slides over a warm gauze. Is there any solid residue left? What happens if the experiment is repeated with other metals such as iron and zinc?

When dilute acids react with magnesium, effervescence takes place with the evolution of hydrogen. On evaporating the solutions left after the reaction, crystalline solids are left on the microscope slides. The hydrogen comes from the acids while the solid residue are called *salts* of the acids. The salts are named as follows:

magnesium	+	***hydrochloric acid***	⟶	***magnesium chloride***	+	***hydrogen***
magnesium	+	***acetic acid***	⟶	***magnesium acetate***	+	***hydrogen***
zinc	+	***sulphuric acid***	⟶	***zinc sulphate***	+	***hydrogen***
iron	+	***hydrochloric acid***	⟶	***iron chloride***	+	***hydrogen***

Thus, salts of hydrochloric acid are called ***chlorides***, those of sulphuric acid are ***sulphates***, of acetic acid are ***acetates*** and salts of nitric acid are ***nitrates***. There are many other acids than those mentioned here, and they produce their own salts. Carbonic acid produces ***carbonates*** and phosphoric acid produces ***phosphates***. While dilute sulphuric acid and dilute hydrochloric acid react with most metals to produce a salt and hydrogen, the action of nitric acid is different.

Activity 5. Take a small amount of solid calcium carbonate in a test tube and about 2 cm^3 of lime water in another test tube. Add about 2 cm^3 of dilute hydrochloric acid to the calcium carbonate. There will be evolution of a gas which when passed into the lime water turns it milky (diagram 70); the evolved gas is carbon dioxide. The resultant solution on evaporation leaves a salt, calcium chloride; water is also formed in the reaction.

calcium carbonate + hydrochloric acid ⟶ calcium chloride + water + carbon dioxide

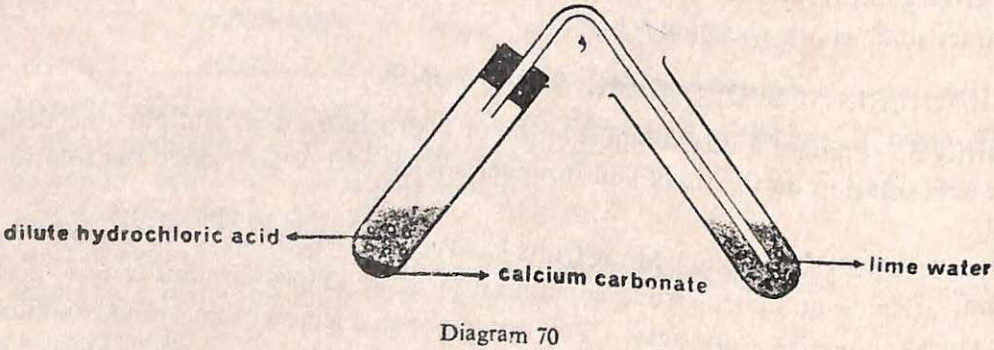


Diagram 70

Other acids on reacting with carbonates show a similar reaction; the products are a salt, water and carbon dioxide. This general reaction can be written as:

carbonate + acid ⟶ salt + water + carbon dioxide

Activity 6. Take some copper oxide, add some dilute sulphuric acid and heat. When sulphuric acid reacts with copper oxide, a blue solution of copper sulphate is formed. Water is the other product.

copper oxide + sulphuric acid ⟶ copper sulphate + water

Copper oxide is insoluble in water and has no action on litmus. It is a basic oxide because, on reacting with an acid, it forms a salt and water. In general, ***an oxide whether soluble in water or not, is called a basic oxide if on reacting with an acid forms a salt and water.***

basic oxide + an acid ⟶ a salt + water

CHARACTERISTICS OF ALKALIS

Activity 7. Rub a little dilute solution of sodium hydroxide between two fingers and then wash your fingers to avoid burning. Repeat this procedure with dilute solution of potassium hydroxide and lime water. How do you feel? Alkalis have a soapy feeling.

Activity 8. Add sodium hydroxide solution to solid ammonium chloride and heat. Smell the gas formed and test the gas with moist red litmus paper. Repeat the experiment using ammonium sulphate and potassium hydroxide or lime water. What happens in each case?

When alkalis are heated with ammonium salts, a gas is evolved which has a characteristic pungent smell and which turns red litmus blue. The gas is ammonia. This experiment cannot, however, be performed with ammonium hydroxide which itself gives ammonia gas on heating.

Activity 9. Add the three indicators : methyl orange, red litmus and phenolphthalein to dilute solution of sodium hydroxide taken in three different test tubes. Note the colour of the indicators in the solutions. Repeat the experiment with solutions of potassium hydroxide, lime water and ammonium hydroxide.

It will be observed that the alkalis turn methyl orange to yellow, red litmus to blue, and phenolphthalein to pink.

REACTION OF AN ALKALI WITH AN ACIDIC SOLUTION

Activity 10. Fill a burette with dilute hydrochloric acid and fit it on a clamp stand. Suck in 25 cm^3 of dilute sodium hydroxide solution in a pipette and transfer it into a clean beaker. Note the temperature of the alkali solution and add a drop or two of methyl orange indicator to it. Now run in the acid solution slowly into the beaker and stir continuously (diagram 71). A stage is reached when even an extra drop of the acid solution turns methyl orange from yellow to pink; note the

volume of the acid used till this stage. Take the temperature of the resultant solution. Is there any change in temperature?

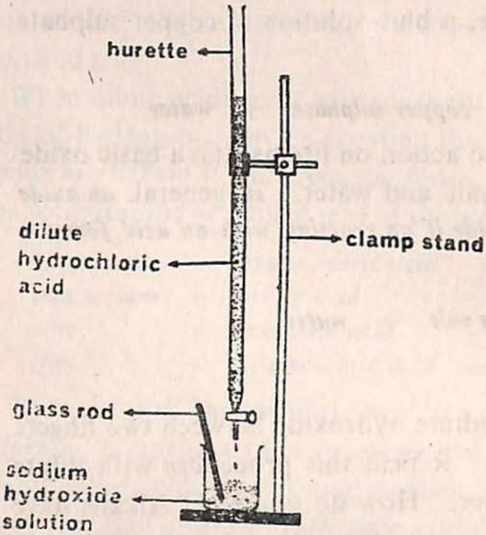


Diagram 71

You will find that there is a temperature rise showing that it is an exothermic chemical reaction. The experiment gives the volume of the acidic solution just needed to react with the alkali solution. The resultant solution is neutral when the acidic and alkali solutions are taken in this ratio, without the indicator. Take on a microscope slide two drops of the neutral solution without the indicator and evaporate to dryness by holding it above a warm wire gauze. Taste a little of the solid residue left on the slide.

You will find that the solid residue tastes like common salt which is sodium chloride. Water is another product of the reaction.

sodium hydroxide + *hydrochloric acid* $\longrightarrow$ *sodium chloride* + *water*

In general, an acid reacts with an alkali to form a salt and water.

acid + *alkali* $\longrightarrow$ *salt* + *water*

Like the insoluble oxides, it can be shown that insoluble hydroxides also form a salt and water on reacting with an acid. ***A base, therefore, reacts with an acid to form a salt and water.*** Such reactions are called ***neutralisation.***

acid + *base* $\longrightarrow$ *salt* + *water*

STRENGTHS OF ACIDIC AND ALKALINE SOLUTIONS

Acid and alkalis could be strong or weak; these words have a different meaning than concentrated and dilute. We should be careful to distinguish between these two ideas.

Activity 11. Take about 2 cm^3 each of dilute hydrochloric acid, dilute sulphuric acid and dilute acetic acid in different test tubes. To each of them add the same length of a magnesium ribbon. Do you notice any difference in the chemical activity of the acids?

Now take about 2 cm^3 each of dilute hydrochloric acid and concentrated acetic acid in different test tubes and add the same length of a magnesium ribbon to each of the acid solutions. Which acid has a greater chemical activity?

In the first case, it is noticed that hydrochloric acid reacts more vigorously than

sulphuric acid, while the reaction of acetic acid is least vigorous. In fact even a dilute solution of hydrochloric acid reacts more vigorously than a concentrated solution of acetic acid. We say that the hydrochloric acid is stronger than the acetic acid.

The strength of an acid depends upon its reactivity while its concentration depends on the quantity of the acid in water. An acid may be more concentrated (less water content) but weaker (less reactive) than a dilute solution of another strong (more reactive) acid.

THE pH SCALE

Like acid solutions, the words concentration and strength have also different meanings for alkaline solutions. The relative strengths of acidic and alkaline solutions are specified by a scale known as the ***pH scale*** which can be found out with the help of a pH paper or a universal indicator.

Activity 12. Put a drop of several acid solutions, distilled water and hydroxide solutions on different strips of a pH paper. Note the change in colour and compare the colours obtained on the strips with those given on the manufacturer's chart; hence, find out the pH values of the solutions.

Activity 13. ***Universal indicator*** is used to find out the strengths of acid and alkaline solutions. Take about 1 cm^3 of several acid and hydroxide solutions: hydrochloric acid, sulphuric acid, acetic acid, ammonium hydroxide and sodium hydroxide in different test tubes and dilute each of them with 15 cm^3 of distilled water. In two other test tubes take 16 cm^3 of distilled water and carbonic acid (prepared by passing carbon dioxide in water). To each of these test tubes add about $\frac{1}{2}$ cm^3 of diluted solution of universal indicator (or the amount suggested according to manufacturer's instructions). Shake the test tubes and compare the colours with those given on the manufacturer's chart; hence, find out the pH values of the solutions.

You have seen that the relative strengths of some of the acids is decided by their reaction on magnesium. How are the strengths related to the pH value of acidic and alkaline solutions?

The acidic solutions have a pH value less than 7 while alkaline solutions have a pH greater than 7. A solution which has a pH of 7 is said to be neutral; distilled water will give a pH of 7.

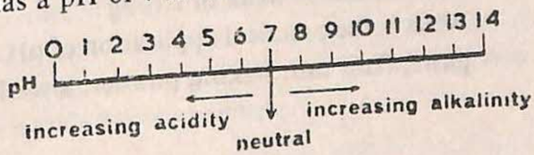


Diagram 72

You will also notice that lower the pH value, greater is the strength of the acidic solution; also, higher the pH value, stronger is the alkaline solution. The pH value ranges from 0 to 14 (diagram 72).

Activity 14. The pH value of soil can be determined as follows. Take a sample of soil in a beaker, add a little water, stir and filter. Test the filtrate with the universal indicator or pH paper to determine the pH of the soil.

The pH value of the soil is of great importance to the farmers. There is an optimum (most suitable) pH for crops and this varies from crop to crop. For example, citrus fruits grow better in a slightly alkaline soil. Physicians also make use of pH values of urine and blood for the diagnosis of diseases.

PROBLEMS

1. What are acidic and basic solutions? How are they obtained?
2. What are indicators? Name three indicators generally used in the laboratory. Mention the colour changes that take place in them in different mediums.
3. You are given a colourless liquid and are told that it contains an acid. What experiments will you perform to verify this statement?
4. What is meant by neutralisation? Describe a method, with a clear diagram, of finding out the exact volume of an acidic solution which will neutralise a fixed volume of a basic solution.
5. Write word equations for the following reactions:
   (*a*) calcium oxide reacting with nitric acid;
   (*b*) barium carbonate reacting with hydrochloric acid;
   (*c*) sodium hydroxide reacting with sulphuric acid;
   (*d*) zinc carbonate reacting with acetic acid;
   (*e*) copper oxide reacting with nitric acid;
   (*f*) magnesium hydroxide reacting with sulphuric acid.
6. What is the difference between a dilute and a concentrated acid? What precautions should you take in preparing dilute sulphuric acid?
7. What is a pH scale? How does it help to find out whether an acidic or an alkaline solution is weak or strong?

   What is the practical application of pH scale? Find out the pH value of a tooth paste, fruit salt, baking powder, a washing soap and a toilet soap.

10 Water and Compounds

You have earlier studied the preparation of crystals of different substances by the action of acids on metals, metallic oxides, hydroxides and carbonates. Crystals of sulphur have also been examined under a microscope.

WATER OF CRYSTALLIZATION

Activity 1. Examine a few crystals of copper sulphate and feel them. Are the crystals dry? Take the crystals in a test tube; hold the tube with a test tube holder and heat it with its mouth slightly inclined downwards (diagram 73). Is there any change in the colour of the crystalline substance?

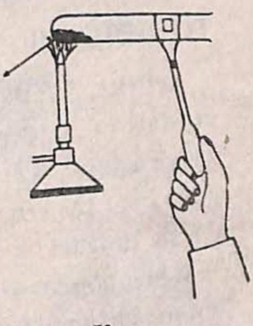


Diagram 73

You will observe that the blue crystals give a colourless liquid on heating which condenses on the cooler part of the tube. When tested with a cobalt chloride paper, the liquid turns the paper pink showing that the liquid is water. The open end of the tube was pointing slightly downwards to prevent the water from running back to the hot part of the test tube which might be broken.

In the heating process, the blue crystals turn into a white solid. Feel the solid residue with your fingers and you will observe that the crystalline structure has been lost. Allow a drop of water to fall on the non-crystalline solid and you will notice that it turns blue again; there is a little heat produced indicating an exothermic chemical reaction taking place between the solid residue and water.

The crystalline structure of copper sulphate is due to the water which is called ***water of crystallization***. Repeat the experiment by heating crystals of washing soda, ferrous sulphate and zinc sulphate separately. You will observe that these also contain water of crystallization. Such compounds containing water are called ***hydrated compounds***. When the water is driven out, the solid left is called ***anhydrous*** (without water) and is ***amorphous*** (non-crystalline) in structure.

Activity 2. Heat gently a few crystals of pure sodium chloride and of potassium nitrate, separately, in test tubes. What do you observe?

Sodium chloride on heating produces a crackling sound (***decrepitates***) and the

bigger particles break up into smaller particles. The potassium nitrate melts and on strong heating produces oxygen which can be tested by a glowing splint. Both the substances, however, give out no water. There are many other compounds which do not contain any water of crystallization.

REVERSIBLE REACTIONS

When hydrated copper sulphate is heated, the products are anhydrous copper sulphate and water. On the other hand the reaction between anhydrous copper sulphate and water forms hydrated copper sulphate.

hydrated copper sulphate $\longrightarrow$ ***anhydrous copper sulphate*** + ***water***
anhydrous copper sulphate + ***water*** $\longrightarrow$ ***hydrated copper sulphate***

Reactions which can go both ways are called ***reversible reactions***; the products can react to re-form the original substances. Another example of a reversible reaction is the action of heat on mercury oxide; the products of decomposition : mercury and oxygen combine easily to form mercury oxide.

TO DETERMINE THE AMOUNT OF WATER OF CRYSTALLIZATION

Activity 3. Weigh a small, clean and dry porcelain crucible. Powder some crystals of copper sulphate in a mortar, fill the crucible about one-third full, and weigh again. The difference in the two gives the mass of powdered copper sulphate. Now heat the crucible to drive off the water of crystallization, allow it to cool and weigh it again.

When copper sulphate crystals are heated, they turn from blue to white. The colour change is not however a sure test that all water of crystallization has been removed, because a few crystals in lower layers may still contain the water. The crucible is therefore heated again for about 10 minutes, cooled and weighed. If the repeated heating, cooling and weighing gives the same mass, then we can be sure that all the water is driven off.

The percentage of water content may be calculated as follows:

(*a*) Let mass of empty dry crucible $= m_1$ g
(*b*) mass of crucible + crystals $= m_2$ g
(*c*) mass of crucible + anhydrous residue $= m_3$ g

Hence, mass of copper sulphate crystals $= (m_2 - m_1)$ g
mass of water of crystallization $= (m_2 - m_3)$ g
percentage of water of crystallization $= \dfrac{(m_2 - m_3)}{(m_2 - m_1)} \times 100$

GROWING LARGE CRYSTALS

When solutions are evaporated, crystals of the compound are obtained; but you will have noticed that they do not all have the same shape. This is due to the fact

that the crystals do not grow freely in all directions. To grow a well shaped crystal, it is essential that it has freedom to grow in all directions.

Activity 4. Slowly add powdered potash alum into some distilled water while it is constantly stirred. You will notice that there is a limit to the amount of alum that can be added to dissolve in the solvent; any further amount of the alum does not dissolve and settles at the bottom. This solution is called a ***saturated solution*** at that temperature.

Heat the saturated solution and cool again to the room temperature. You will observe that the alum settled at the bottom dissolves with rise of temperature and reappears on cooling. The solubility of a substance increases with rise in temperature. Filter the cold saturated solution into a clean beaker to remove any solid that may be present. Now suspend a well shaped crystal of alum by means of a thread tied to a glass rod so that the crystal is immersed in the solution (diagram 74). Cover the beaker with a piece of paper to keep away dust particles; set aside the beaker and watch the crystal grow very slowly. The water slowly evaporates as the crystal grows. You may notice crystals appearing at other places also; these should be removed. To grow a large crystal usually takes several weeks.

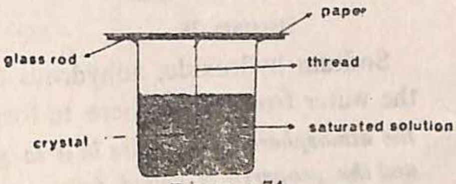


Diagram 74

When the water evaporates, the suspended crystal acts as a seed crystal and grows bigger as the solid coming out of the saturated solution is deposited on it. The solution should be kept dust-free and small crystals appearing at other places are removed to avoid other centres of crystal growth.

Repeat the experiment with other compounds like copper sulphate, potassium dichromate and potassium nitrate. Diagram 75 shows the shape of well formed crystals of some compounds.

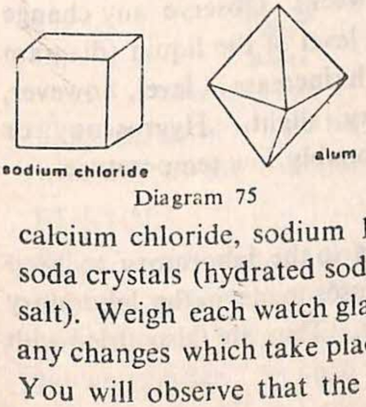


Diagram 75

EFFLORESCENCE AND DELIQUESCENCE

Activity 5. Place small amounts of the following substances on separate watch glasses : calcium oxide (quicklime), black copper oxide, anhydrous calcium chloride, sodium hydroxide, magnesium chloride, common salt, washing soda crystals (hydrated sodium carbonate) and sodium sulphate crystals (Glauber's salt). Weigh each watch glass and set it aside exposed to air for a few days. Observe any changes which take place and weigh the watch glasses with their contents again. You will observe that the watch glasses containing crystals of washing soda and

sodium sulphate lose weight and become powder. They lose their water of crystallization and hence their crystalline structure (diagram 76). ***Substances that lose all or a portion of their water of crystallization when exposed to air are said to be efflorescent and the property is called efflorescence.*** The process is aided by an increase in temperature and a dry atmosphere.

In the above experiment, watch glasses containing quicklime, anhydrous calcium chloride, black copper oxide, sodium hydroxide, common salt and magnesium chloride increase in weight. They form either solution or become damp (diagram 77). They absorb water from the atmosphere.

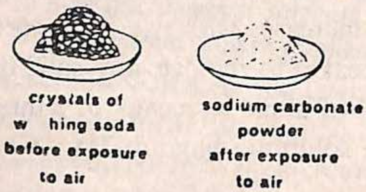


Diagram 76

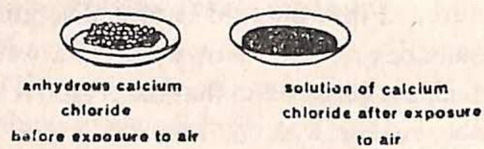


Diagram 77

Sodium hydroxide, anhydrous calcium chloride and magnesium chloride absorb the water from atmosphere to form a solution. Such ***solids which absorb water from the atmosphere and dissolve in it to give a saturated solution are said to be deliquescent and the property is called deliquescence.*** Common salt becomes damp, particularly in humid weather, but this is because of the presence of traces of magnesium chloride and calcium chloride in it as impurities.

Solids like copper oxide and quick lime also absorb water from the atmosphere but they do not form a solution with water. Such solids are said to be ***hygroscopic.*** The term is also applied to liquids like concentrated sulphuric acid which absorbs water from the atmosphere.

Activity 6. Half fill a beaker with concentrated sulphuric acid and mark the level of the liquid on the outside of the beaker. Set it aside exposed to air for a week. Observe any change in the level of the liquid (diagram 78). The increase in level, however, is very slight. Hygroscopy or deliquescence is aided by damp atmosphere and a reasonably low temperature.

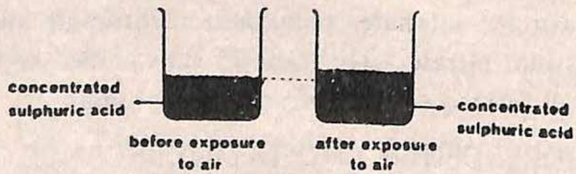


Diagram 78

DRYING AGENTS

Chemists use deliquescent and hygroscopic substances in the laboratory to keep another solid dry if it has a little attraction for water. Gases made in the laboratory are generally moist as they are mixed with water vapour. They are also dried with either a deliquescent or a hygroscopic substance.

Solids which need to be dried are kept in an apparatus called a ***desiccator*** (diagram 79). The atmosphere inside a desiccator is kept dry by the presence of anhydrous calcium chloride silica gel or concentrated sulphuric acid, which readily absorb water vapour. A greased lid is used to make it absolutely air-tight.

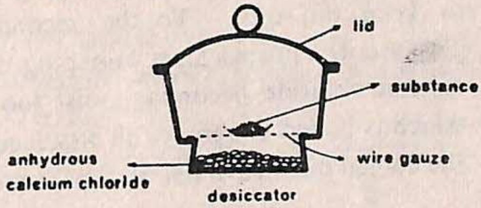


Diagram 79

Gases are dried in various ways depending upon the gas to be dried; clearly the ***drying agent*** must be a substance which does not react chemically with the gas. Usually anhydrous calcium chloride and concentrated sulphuric acid are used. The apparatus used depends upon the choice of the drying agent. Three typical arrangements are shown in the diagram 80.

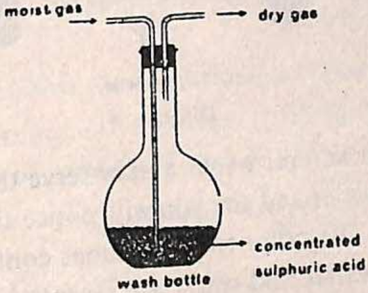


Diagram 80 (a)

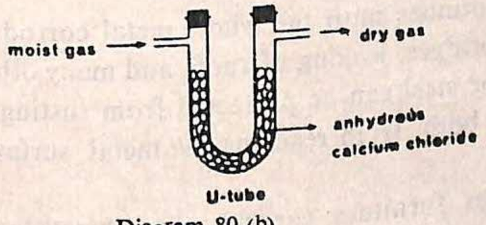


Diagram 80 (b)

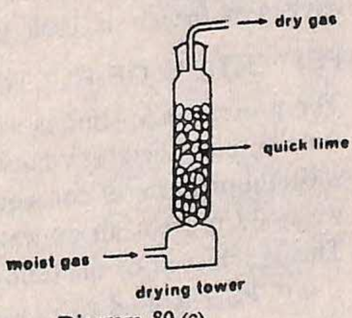


Diagram 80 (c)

Silica gel is also now being used for drying gases. It does not react chemically with any of the common gases.

RUSTING

When certain substances are exposed to air they undergo some changes. Look at old iron nails, scraps of iron and corrugated iron sheets used for roofing. You will notice that all these materials which look bright when new are covered with a reddish brown powder. In such a case the iron is said to ***rust*** or ***corrode***.

Activity 7. Put new, fresh-looking iron nails in three test tubes. To one tube add distilled water and insert a plug of glass wool in the mouth of the test tube to keep out dust. To the second tube add anhydrous calcium chloride on glass wool. Place a glass wool plug on the mouth of the test tube to prevent the calcium chloride becoming moist too soon. To the third tube add distilled water which is boiled to remove all dissolved air. Put some vaseline on the top surface of the cooled distilled water so that it makes an air-tight seal (diagram 81).

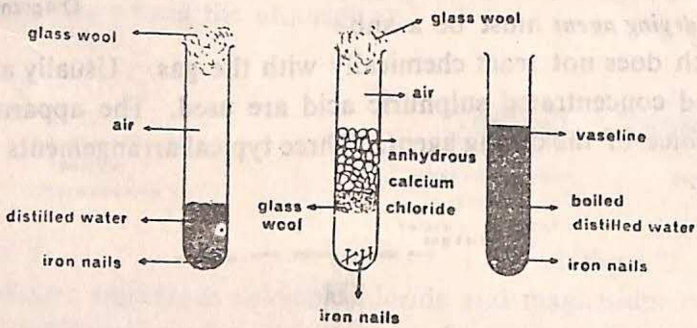


Diagram 81

Leave the test tubes for several weeks and observe them from time to time. The first tube contains both water and air; you will notice that brown rust is formed on the nails in the test tube. The other two test tubes contain only air and only water respectively. Hence, both air and water are essential for rusting to take place.

Chemical analysis shows that the rust is hydrated iron oxide. In this process, oxygen of the air is used up.

PREVENTION OF RUSTING

The process of rusting is wasteful and continues until the whole metal corrodes. Rusting may therefore cause collapse of bridges, leaking of roofs and many other wasteful or harmful consequences. Iron or steel can be protected from rusting if we could prevent air or water vapour, or both, from reaching the metal surface. This is achieved by the following methods:

(*a*) ***Paint*** is used to prevent steel bridges, furniture, car and other objects from rusting.

(*b*) ***Electroplating*** is done to deposit a thin film of chromium or nickel on the steel surface, this way the metal does not corrode easily.

(*c*) ***Greasing*** of tools and utensils, which are not regularly used, prevents them from rusting; these objects are rubbed with vaseline or oil.

(*d*) ***Galvanising*** is a process in which corrugated iron sheets and pipes carrying water are coated with zinc by dipping them into baths of molten zinc.

PROBLEMS

1. What are hydrated compounds? Give some examples. What are the observations when crystals of copper sulphate are heated? What precautions are taken while heating these crystals?
2. What is a reversible reaction? Give two examples. Describe experiments to show a reversible reaction.
3. What is water of crystallization? Explain how you can determine experimentally the percentage of water of crystallization in a hydrated compound.
4. What happens when the following substances are exposed to air? (*a*) anhydrous calcium chloride; (*b*) washing soda crystals; (*c*) concentrated sulphuric acid; (*d*) impure common salt. Explain any changes that take place in them.
5. What are drying agents? Show some arrangements of apparatus used for drying gases.
6. Describe an experiment to show the conditions necessary for the rusting of iron?
7. Compare rusting and burning of substances. What are the different methods used for the prevention of rusting of iron?

11 Fruits and Seeds

The flower is a reproductive organ in plants. Its various parts undergo important changes during the various stages of reproduction: pollination, fertilization and germination.

The transfer of pollen from the stamens to the stigma, of the same or another flower, is called ***pollination***. When the pollen grains reach the stigma, they give out a pollen tube. The tube gradually extends in the style and enters the ovary. The male cell, which is the 'active' part in the pollen tube fuses with a female egg cell (diagram 82); this process is called ***fertilization.***

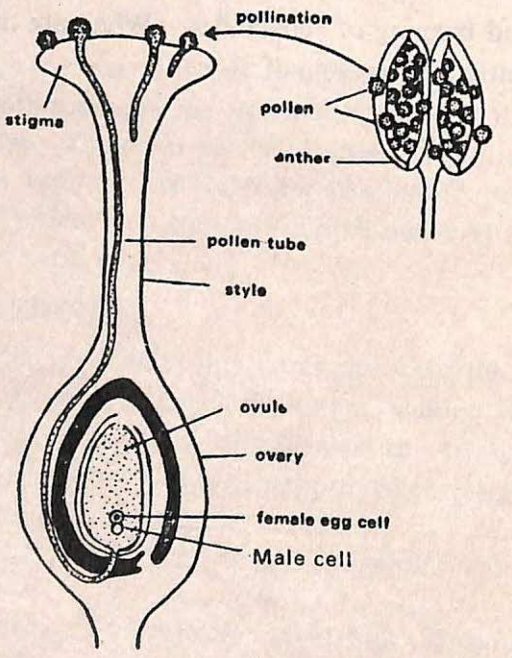


Diagram 82

CHANGES IN A FLOWER AFTER FERTILIZATION

Various parts of the flower undergo gradual changes after fertilization takes place. These changes are shown below:

(*a*) Calyx (sepals) ⟶ sheds
(*b*) Corolla (petals) ⟶ sheds

(c) Androecium (stamens) → withers and sheds
(d) Gynaecium (ovary)
  (i) Style and stigma → withers and sheds
  (ii) Carpel wall → becomes the fruit wall (*pericarp*)
  (iii) Ovules → become the seeds
  (iv) Egg cell (*ovum*) → becomes the *embryo*

Thus the sepals, petals, stamens, style and stigma generally wither and fall to the ground after serving their function leading to fertilization. The energy of the plant is now directed to the fertilized ovules and the ovary. The ovary generally grows in size rapidly and becomes the fruit.

THE FRUIT

The fruit of a plant is the ripened ovary. Some fruits are formed only from the ovary; these are the *true fruits*. Others, such as the apple, include parts like the receptacle of the flower as well; these are called the *false fruits*.

Mango, guava, tomato, orange and lime are examples of fleshy juicy fruits. Examples of *dry fruits* are nuts, garden pea pod, poppy capsule, maize and beans.

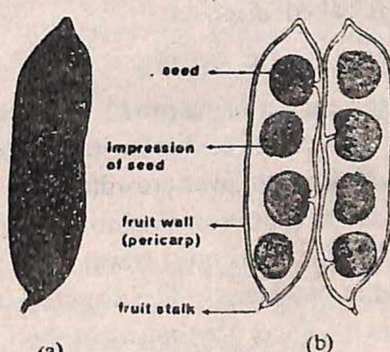


Diagram 83

Activity 1. A typical example of a dry fruit is the bean or pod of the pea plant. You will notice that the fruit shows bulges at several places when ripe; these indicate the position of the seeds inside (diagram 83 *a*).

Press firmly at the edges of a ripe bean and its walls split open. You will observe that each seed is attached to a thin ridge along the edge of the pod (diagram 83 *b*); this ridge is called the *placenta*. A developing seed receives food supplies through the placenta. When the seed is detached from the placenta, it will leave a scar on the seed.

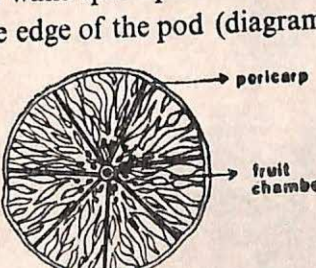


Diagram 84

Activity 2. Cut open a lime and observe its various parts. The fruit wall, pericarp, forms a thick, leathery skin (diagram 84). The *fruit chamber* contains a number of small seeds surrounded by the juicy material.

TO DIFFERENTIATE BETWEEN A SEED AND A FRUIT

It is easy to distinguish a fruit when it is large and juicy. A small dry fruit, however, looks almost like the seeds of other fruits. For example, the maize or wheat grain is a fruit.

A seed has one scar showing the place where it was attached to the placenta inside the fruit. A fruit has, however, two scars; one where it was attached to the stalk and a second scar of the style showing where the withered style was once attached to the ovary.

FUNCTION OF A FRUIT

A fruit is the food of man and animals. Besides being useful in this way, a fruit has an important role to play in the continuance of plant life. In the first instance, it protects the developing seeds. When seeds are soft and tender they require protection from damage against disease, drying action of the atmosphere and from animals. The fruit wall and the jelly-like material in the fruit chamber provides physical protection; some fruits secrete a sticky, distasteful substance which keeps animals away. The green colour of many fruits camouflages them against the background of leaves.

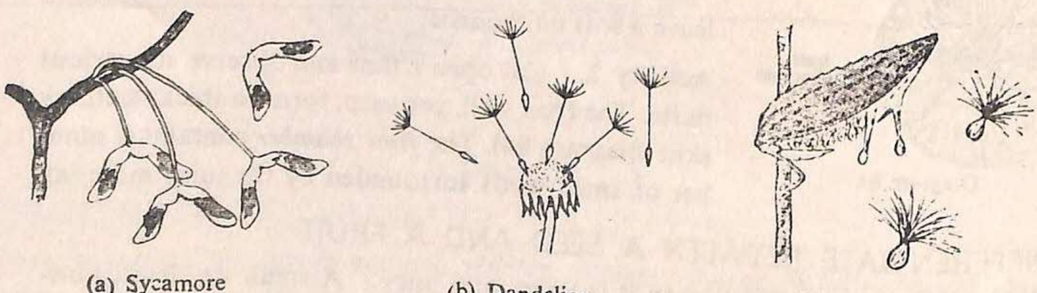
Secondly, a fruit helps scatter the seeds when they are ripe. This scattering of seeds is called ***dispersal***.

DISPERSAL OF SEEDS

In its life time a plant produces several thousand seeds. If all these seeds were to fall on the ground and grow into plants, there would not be enough sunshine, water and soil due to over-crowding.

To avoid over-crowding so that more favourable conditions of growth are available, the seeds must travel away from the plant. A plant itself is rooted to the ground at one place. The dispersal of seeds is aided by the ovary wall or receptacle in plants. There are four main ways in which the dispersal of fruits and seeds takes place.

(*i*) ***By wind***. Some seeds and fruits are light and have thin extensions which make them easily air borne. Examples of such air borne fruits are shorea, sycamore, dandelion and silk cotton (diagram 85).

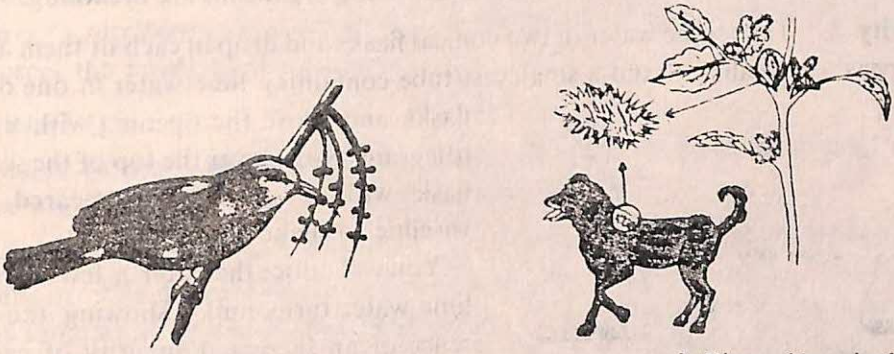


(a) Sycamore (b) Dandelion (c) Calotropis

Examples of wind dispersal

Diagram 85

(*ii*) ***By animals.*** Fleshy and juicy fruits are eaten by animals and man. The seeds are then scattered away from the parent plant. Examples of such dispersal by animals are mango, papaya and berries (diagram 86 *a*).



(a) Dispersal by birds (b) Dispersal by animals

Diagram 86

Some fruits have hooks or spines which cling on to the coat of passing animal. (diagram 86 *b*). Such fruits are called ***burr-fruits***; examples are love-grass and xanthium.

(*iii*) ***By water.*** Plants growing close to the rivers and the sea often have seeds and fruits dispersed by the water. The coconut is a typical example. Its wall is fibrous and makes the fruit float. The single seed is provided with water and food inside for survival over many days. Lotus fruit and weeds are similarly dispersed.

(*iv*) ***By exploding.*** The Balsam, pea ~~and~~ poppy disperse their seeds without being aided by any outside agency. The fruits become dry on ripening; when swayed by wind or touched by hand, they split open suddenly and fling their seeds some distance away (diagram 87).

(a) Poppy (b) Balsam

Dispersal by explosion

Diagram 87

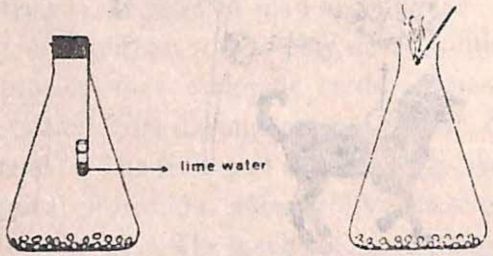
THE SEED

The life of a new plant starts from a seed and it goes through the stages of growth, reproduction and death. The process of a seed developing into a living plant is

called *germination*. A seed, however small and hard it may appear, is a living organism waiting for favourable conditions in which to germinate.

Some seeds are not alive; some may not have fully ripened. These seeds will not germinate. All live seeds, however, like other living organisms are breathing.

Activity 3. Take some water in two conical flasks and drop in each of them about fifteen peas or beans. Stand a small test-tube containing lime water in one of the flasks and close the opening with a cork (diagram 88 *a*). Cover the top of the second flask with a glass plate smeared with vaseline to make an air-tight fit.



(a) Germinating peas give out carbon dioxide (b) Oxygen is consumed by germinating peas

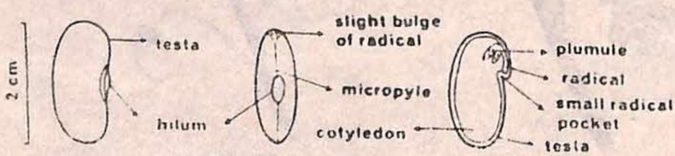
Diagram 88

You will notice that after a few days the lime water turns milky showing the presence of an increased quantity of carbon dioxide. If a lighted taper is introduced into the second flask, it goes out (diagram 88 *b*) showing that the oxygen which was in the flask has been consumed. The seeds must have taken the oxygen, giving out carbon dioxide.

STRUCTURE OF A BEAN SEED

Most seeds are hard and difficult to open but, if soaked overnight in water, they swell and soften.

Activity 4. Soak a large bean seed overnight and examine it the next morning. The seed shows an oval-shaped scar, called the ***hilum***, showing where it was attached to the pod. If you look closely through a magnifying glass, you will observe a tiny hole, called the ***micropyle***, at one end of the seed scar. Squeeze the seed gently; water and air bubbles are seen to escape from the micropyle; the water entered the seed through the hole when it got soaked. During fertilization, the micropyle is the hole through which the pollen tube enters the ovule.



(a) side view (b) front view (c) sectional view

A bean seed

Diagram 89

Above the micropyle, the seed shows a slight bulge. The seed is covered by a smooth ***seed coat*** or ***testa*** which can be removed once the seed is soaked. Inside the seed

coat is the *embryo* which is a miniature plant complete with a root, stem and leaves.

The small root is called the *radicle* which causes the slight bulge of the seed when seen with the testa over it. There is a very short stem with its little leaves; this is called the *plumule*. The embryo can be split open into two sections called the *seed leaves* or *cotyledons;* these are special leaves which contain a lot of stored food and protect the inside of the embryo.

GERMINATION

The process of seeds developing into living plants is called germination. This happens when the right conditions are obtained.

Activity 5. Take five test tubes for investigating the suitable conditions for germination. Pea or mustard seeds are suitable for this experiment. The tube *A* contains some water in which the seeds are put. The tube *B* also contains water and the seeds but is covered with black cloth or aluminium foil to exclude light. The water in tube *C* is boiled to expel dissolved air and cooled before the seeds are put in and molten vaseline poured on top to seal the tube. Some dry cotton or sand is put in tube *D* in which the seeds are put. The tube *E* contains some water and seeds but is kept in deep freeze so that the temperature is very low. Examine the tubes daily and record the observations. In which tubes has germination taken place? Are the plants in these tubes similar in appearance?

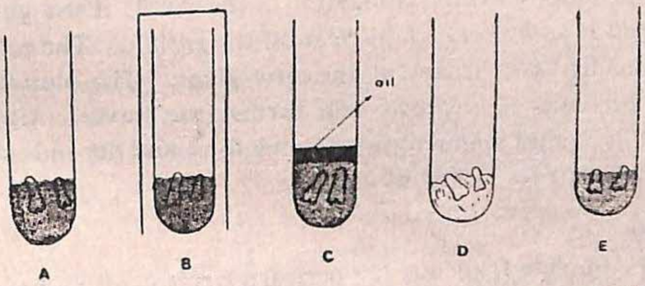
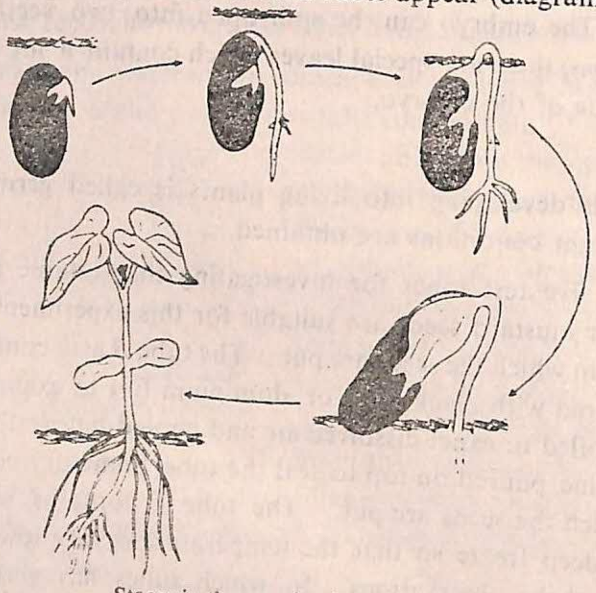


Diagram 90

After a few days you will observe that the seeds in *C*, *D* and *E* have not germinated. The seeds in *A* and *B* alone germinate but while the plants in *A* are healthy, those in *B* are thin, long and yellowish in colour. This clearly shows that all three conditions: water, air and suitable temperature are necessary for the germination of seeds and sun light is necessary for a healthy growth after germination.

Seeds packed in bags do not germinate because they are dry. When a dry seed is soaked in water, the cotyledons absorb water and gradually change into soluble form. This enables the embryo to utilise the food stored in the cotyledons and germinate.

The testa also becomes soft so that the radicle pushes out of it by splitting it open. The radicle turns downwards no matter in what position the seed is planted. As the radicle grows longer, root hairs and branch roots appear (diagram 91).



Stages in the germination of a bean
Diagram 91

The next stage in germination is the elongation of the shoot; it straightens splitting open the seed coat and lifts the cotyledons clear off the ground. The cotyledons now unfold to become the first two leaves of the new plant. The plumule which lies between the two cotyledons now grows and forms true leaves. Until the green leaves appear, the plant cannot manufacture its own food and depends upon the food stored in the cotyledons for its supply of energy.

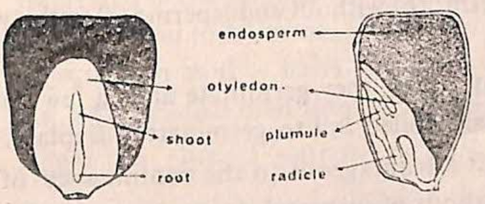
MAIZE (Zea Mais)

The maize seed is a complete fruit but the pericarp (fruit wall) and the testa (seed coat) are so closely united that they cannot be separated. The grain is like a tooth and yellow in appearance except for a light coloured patch on one side which is the embryo.

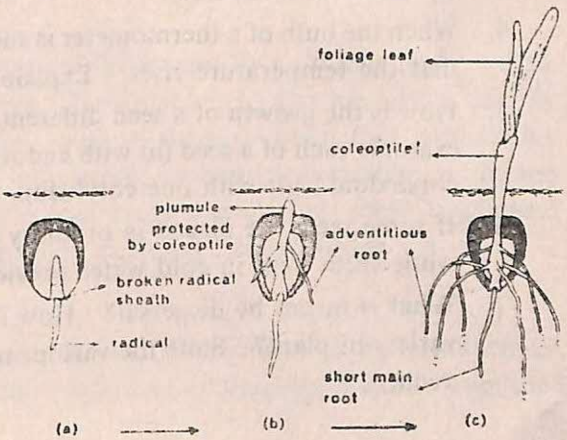
Activity 6. Soak a grain of maize in water. It takes over two days before the seed becomes soft. Now cut the seed lengthwise with a sharp blade. You will notice the radicle pointing towards the narrow end (apex) and the plumule pointing in the opposite direction (diagram 92). These two are attached to a single cotyledon which partly surrounds them. Behind the cotyledon is the yellow ***endosperm*** which forms the food store.

When the maize grain germinates, the radicle appears first, bursting through its

protective sheath. It forms a number of side roots forming a fibrous root system. In the mature plant, ***adventitious roots*** arise from the nodes (diagram 93). The plumule is also protected by a sheath called ***coleoptile*** which lengthens as the plumule grows until the surface is reached. The cotyledon remains within the grain utilising the food stored in the endosperm and passing it on to the developing embryo.



(a) front view (b) sectional view
Structure of a maize seed
Diagram 92



Germination of maize
Diagram 93

TYPES OF SEEDS

The structure of nearly all seeds is like one of the two studied above. Those which have two seed-leaves are called ***dicotyledons***. Gram, pea, bean and castor are examples of dicotyledonous seeds. The full grown plant has one main root with small ones growing from it. The leaves of dicotyledonous plants have a midrib which runs along the length of the leaf blade, and a network of small veins cover the leaf blade. A leaf is attached to a single stalk.

Some seeds have only one cotyledon and are called ***monocotyledons***. Wheat, rice, maize, bamboo, onion, oat and barley are examples of monocotyledonous seeds. The full grown plant has a fibrous root system; adventitious roots also grow from the nodes. The leaves of monocotyledonous plants have a number of veins which run parallel along the length of the leaf blade; these leaves have no stalk and are attached to the stem in such a way as to form a sheath on the stem.

PROBLEMS

1. What is the advantage to a plant of having a large seed? Why do seeds gain weight rapidly at first when planted and then lose weight for the next few days?

2. Give three differences between seeds and fruits. Draw clear diagrams showing the structure of a maize and a bean seed. In what ways do the plants from these seeds differ?
3. When seeds are soaked in water overnight, removed from water and squeezed, water comes out of the seeds. From where does the water come out? Explain the function of the hole.
4. When the bulb of a thermometer is surrounded by germinating seeds, it is noticed that the temperature rises. Explain what happens.
5. How is the growth of a seed different from the growth of a crystal? Name one example each of a seed (*a*) with endosperm; (*b*) without endosperm; (*c*) with two cotyledons; (*d*) with one cotyledon.
6. If some seeds are placed in ordinary tap water, they germinate after a few days while seeds kept in cold water previously boiled fail to germinate. Explain.
7. What is meant by dispersal? How is it advantageous to the continuance of a variety of plant? State the various methods of dispersal giving one example of each.

12 Plant and Animal Cells

A giant tree and a huge elephant are some of the largest living things in the world. It is easy to observe them grow or move. However, biologists have been equally interested in the smallest living organisms, some of them so small that without the aid of special instruments their study is impossible. A hand lens enables us to see objects such as root hairs and parts of a seed more clearly but some organisms are even smaller than these. For their study we require a ***microscope.***

HOW TO USE A MICROSCOPE?

Diagram 94 shows the structure of a microscope. The object to be examined is placed on the ***stage*** in the middle of the hole and viewed through the tube from the ***eye piece*** end.

Activity 1. Place the microscope in position near a window to allow sun light to fall on the mirror; in the absence of natural light, place a lamp about 12 cm away from the mirror. Next, rotate the nose piece so that the low or medium power ***objective*** is above the hole. Now look through the tube and rotate the mirror until the reflected light comes through the hole into the tube.

The material to be examined is placed on a microscope slide, and the slide is kept on the stage such that the object is in the middle of the hole. Next, keeping your eye in level with the stage, lower the tube until the objective is about 5 mm above the slide. The objective should never be brought closer, otherwise it might touch the slide

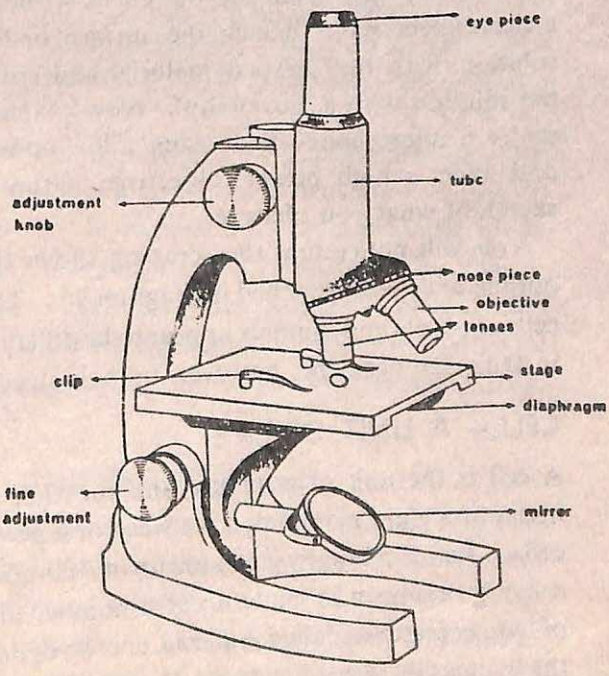
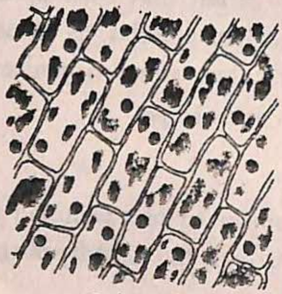


Diagram 94

and break it; what is more important, the objective lens might get scratches on it. Now look through the eye piece, and move the tube upwards gradually until the material to be examined is clearly in focus.

EXAMINATION OF CELLS UNDER A MICROSCOPE

Activity 2. Cut an onion into half and remove one of its thick leaves. Remove the inside skin of this leaf; the leaf peels off very easily. Now place a small piece of this skin on a microscope slide, cover it with water, and slowly lower a 'cover slip' on it without letting in air bubbles or letting the skin roll up. Examine the specimen under the microscope.



Onion cells
Diagram 95

Next, cover the onion skin with iodine solution instead of water and repeat the observation. You will notice the structure of the skin as shown in diagram 95. The skin is seen to be built up of a number of regularly arranged units. Draw in your notebook a simple diagram showing the structure of onion peel as seen under a microscope. The units are rectangular in shape with a circular darker spot in the middle. The regularly arranged units are called ***cells***.

Activity 3. Place a drop of iodine solution or methylene blue solution on a slide. Scrape the inside of your cheek with the blunt end of a clean ***scalpel*** or with a clean finger nail. Touch the surface or the solution with the scraped material and cover the solution with a 'cover slip'. Now examine under a microscope—first using a low power, and then a high power, objective. Draw a sketch of what you observe.

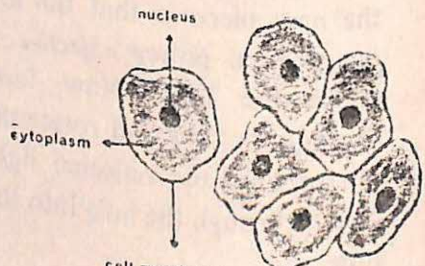


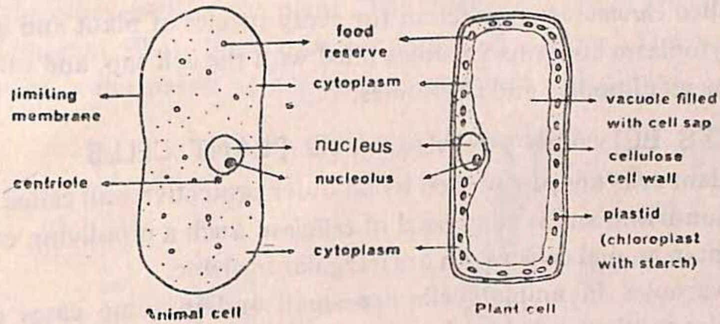
Diagram 96

You will notice that the scraping shows the outline of cells as sketched in diagram 96. The cells of plants and animals appear to be different in their arrangement; however, in their structure they have much in common.

CELL—A UNIT OF LIFE

A cell is the unit of structure and function of living organisms. Whether a tiny insect or a giant mammal, a sea weed or a perennial tree, all of them are made up of cells. Just as a building is made up of a number of bricks arranged in different ways, a living organism is made up of a number of cells joined together. The smallest of living creatures, called ***protozoa***, consist of only one cell. Like all living organisms, the living cells breathe, eat and digest food, move about and reproduce.

The living matter in a cell is called the ***protoplasm***. It consists of mainly two parts —the ***nucleus*** and the ***cytoplasm***. Inside all living cells is a dense material which looks darker than the surroundings when stained; this rounded body is called the nucleus (diagram 97). The nucleus controls all activities of the cell. The nucleus has its sub-structure called the nucleolus which can be viewed only when observed through a high power microscope.



(*a*) (*b*)

Diagram 97

Around the nucleus is a clear and jelly-like material called the cytoplasm; it forms the main body of the cell. The cytoplasm shows some clear spaces called ***vacuoles***. The vacuoles of animal cells are generally small and numerous while inside large plant cells most of the space is occupied by the vacuoles. The vacuoles contain a material called the ***cell sap*** which consists of water containing sugar and mineral salts.

The cytoplasm contains other structures also; some of these are named golgi bodies, ribosomes and ***plastids***. The plastids are disc-shaped dense bodies present in plant cells. The most important among the plastids are the ***chloroplasts*** which look green in colour due to the pigment ***chlorophyll*** present in them. The chlorophyll is responsible for the process of photo-synthesis which goes on in plants in the presence of sun light. Those plants which do not manufacture their own food, e.g., mushrooms, moulds and bacteria, and animals do not have chloroplasts in their cells.

SIMILARITIES BETWEEN ANIMAL AND PLANT CELLS

(*a*) Plant and animal cells have a similar function in the growth and reproduction of living organism. All live cells breathe, move, are sensitive to external stimuli, eat and digest food, excrete and reproduce.

(*b*) Both types of cell have a similar structure. The protoplasm is surrounded by a thin ***plasma membrane***. The membrane, while the cell is living, is

selectively *permeable* and controls the entrance of materials from its surroundings into the protoplasm.

(*c*) The protoplasm contains a nucleus and the cytoplasm. The nucleus is the control centre of a cell and has a fixed number of structures inside it, which are called *chromosomes*, different for every species of plant and animals.

(*d*) The cytoplasm contains vacuoles filled with the cell sap, and other structures such as golgi bodies and ribosomes.

DIFFERENCES BETWEEN ANIMAL AND PLANT CELLS

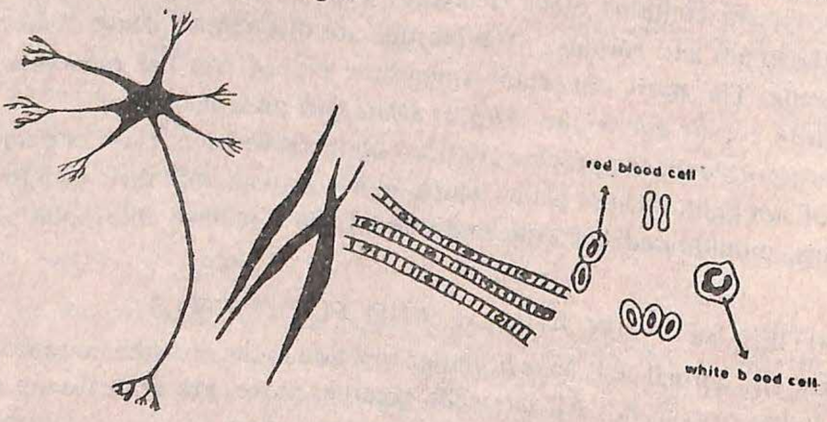
(*a*) The plant cells are surrounded by an outer protective wall called the cell-wall. It is non-living and is composed of *cellulose*. Such a non-living cell-wall is not present in animal cells which are irregular in shape.

(*b*) The vacuoles in animal cells are small and in some cases absent. The vacuoles in plant cells are large and become bigger with the growth of the cells.

(*c*) The plastids of all kinds are absent in animal cells. The animal cells have to obtain their supply of food from outside sources. Some plant cells have chloroplasts which enable them to manufacture their own food.

CELL SPECIALIZATION

Cells in animals and plants vary in size, shape and their internal structure to suit the particular function inside a living organism. This is called specialization. A cell is as small as five-thousandth of a millimetre, as in the case of some bacteria, or as long as 15 cm, as in the case of the ostrich egg. However, most of the cells are about a hundredth of a millimetre in length.



(*a*) (*b*) (*c*) (*d*)

Diagram 98

The nerve cells (diagram 98 *a*) which carry messages from one part of the body to another, and the muscle cells which contract and relax to cause movement (diagram

98 *b* and *c*) are long. The muscle cells attached to the bones have a number of nuclei while the red blood cells in man (diagram 98 *d*) have no nucleus.

Specialized cells carrying out specific functions also are present in plants. The function of the xylem cells is to transport water and dissolved mineral salts from the roots to the other parts of the plant. The xylem cells are of two types: tracheids and vessel (diagram 99 *a*); these cells are long and slender. These are dead cells. In the tracheids, water passes across through openings called pits.

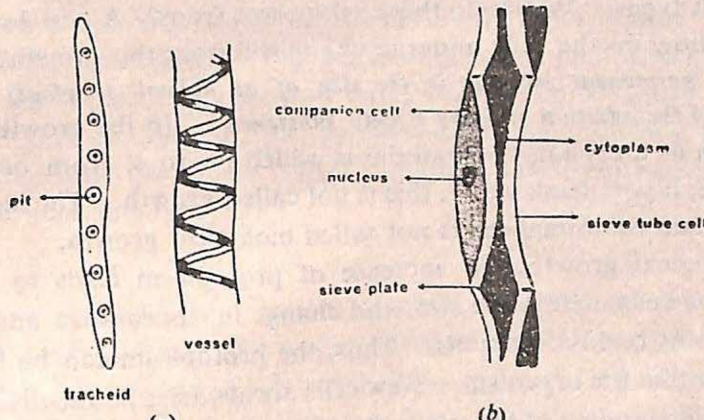


Diagram 99

The phloem cells enable the transport of manufactured food from the leaves to other parts of the plant. These cells chiefly consist of sieve tube cells and companion cells (diagram 99 *b*). These are both living cells. The sieve tube cells are joined end to end with perforations, called sieve plates, between them. The sieve tube cells have no nuclei.

In many types of animals and plants, the cells are not only different in structure but also have specialized functions to perform. For example, the cells of the stomach help digestion of food while those of the lung are good for exchange of gases.

TISSUE AND ORGAN

A number of cells of the same type, having the same structure and function usually work together; such a group of cells is called a ***tissue***. Examples of tissues are muscle tissues, nervous tissues and ***connective tissues***. The connective tissues include the bone and ligaments.

For a proper functioning of our body, there are many parts in which several tissues work together in combination. When two or more tissues work together, such combinations are called ***organs***. The heart, lung, stomach and brain are examples of organs in our body. The heart, for example, is made up largely of muscle tissues which are held together by connective tissues. The stomach is an organ whose

function is to break down the food we eat into smaller particles; it has muscle tissue, glandular tissue and other tissues which enable it to carry out this function.

The leaf, root and flower are examples of plant organs. Each organ has a specific function and the tissues in it enable it to carry out this function.

CELL DIVISION AND GROWTH

Cells are the building blocks of life. Some plants and animals consist of only a single cell; however, most of the familiar organisms consist of a very large number of cells of different types. Where do these cells come from? A new born baby grows into an adult; how do the cells undergo changes during this growth?

Growth is a permanent increase in the size of an animal or plant; this increase is brought about by the addition of more "body substance". In the growth of non-living substances such as a crystal, the material is added on to it from outside. In the biological sense, if you drink water, this is not called growth. The mere absorption of water by a plant or animal cell is not called biological growth.

During biological growth, an increase of protoplasm leads to multiplication of cells, and new cells increase in size, and change in appearance and structure, to carry out different bodily functions. Thus, the protoplasm can be formed at any suitable place within the organism. New cells always arise by the division of parent cells. This understanding of the similarity of life processes among living organisms has been one of the most important steps in biology.

PROBLEMS

1. What are the largest single animal cells?
   Which cells in the animal body possess extensions of cytoplasm? What is the purpose of these extensions?
2. What is the significance of the fact that all cells have a similar structure and function? What are these similarities?
3. How do animal and plant cells differ in structure and function? What is meant by specialization in cells? Give some examples.
4. Explain with some examples what is meant by tissues and organs.
5. What is meant by growth? How does it take place? How does the cell theory explain growth? In what way is growth in animals different from that in plants?

13 Unicellular Animals (Protozoa)

While most animals are made up of a number of cells held together, the single-celled animals are the most simple in structure and the finiest organisms in nature. Many such simple and microscopic organisms are found in water. A drop of pond water may contain thousands of tiny organisms. The small specks of grey matter moving over the surface of most pond mud, when examined, may be found to be living animals such as *Amoeba;* the *paramecium* is seen floating in pond water. Both these animals are placed in a group of animals called *protozoa;* they are single-celled or uni-cellular animals.

AMOEBA

Although found in mud at the bottom of pools and ditches, the amoeba occurs widely in soil, fresh and even salt water. The largest *amoebae* (plural of amoeba) can just be seen with the naked eye but their structure can be examined only when seen through a microscope.

The size of an amoeba increases as it grows upto about $\frac{1}{2}$ mm. The shape changes continuously as it moves; it usually possesses one or more blunt projections called *pseudopodium* (diagram 100).

Inside the cellular membrane is a clear layer of cytoplasm called the *ectoplasm*, which is distinct from the inner fluid cytoplasm called the *endoplasm*. Like all cells, within the cytoplasmic fluid is a round nucleus. The cytoplasm also contains a few food vacuoles and one or more *contractile vacuoles.*

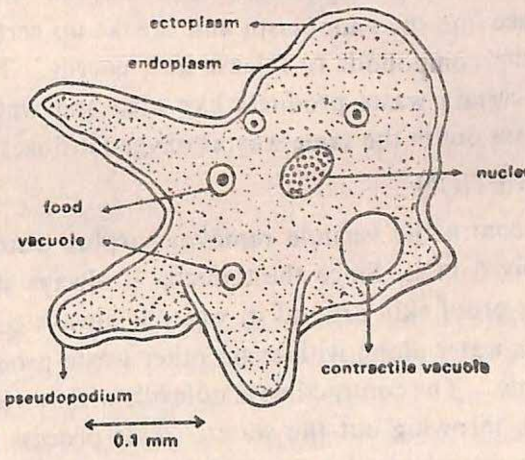


Diagram 100

MOVEMENT

When observed under a microscope, it will be noticed that an amoeba changes its shape continuously. The pseudopodia are given out in various directions due to the movement of the fluid in endoplasm into the ectoplasm. An amoeba moves in contact

with a solid surface by putting out new pseudopodia and withdrawing others; thus a gradual locomotion takes place in one direction.

FEEDING

An amoeba feeds on organic matter such as tiny pond organisms. When it comes in contact with any food particle, the pseudopodia extend round the particle and engulf it (diagram 101). The captured food particle is surrounded by a layer of water; this is called the food vacuole.

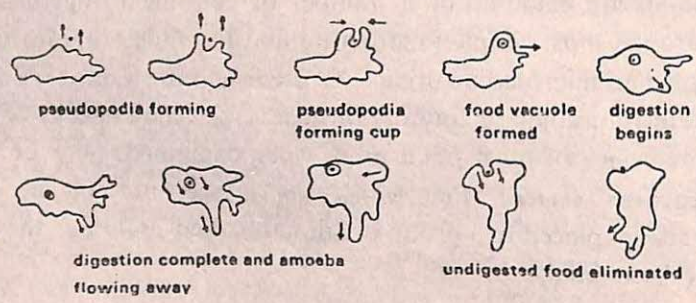


Diagram 101

The endoplasm surrounding the food vacuole next secretes enzymes. Digestion takes place when the enzymes pour into the food vacuole to form certain soluble substances which diffuse into the endoplasm. The amoeba then moves away leaving behind undigested matter which is thrown out at any point of the ectoplasm.

RESPIRATION

Like all other living organisms, the amoeba takes in oxygen and gives out carbon dioxide during respiration. The oxygen diffuses through the whole ectoplasm surface into the endoplasm and breaks up certain chemicals of the protoplasm into simpler compounds to release heat energy. In the process, oxidation takes place and certain waste products like urea and water are formed. The carbon dioxide diffuses out in the same way as oxygen diffuses inside.

EXCRETION

The contractile vacuole removes surplus water together with any waste products dissolved in it. Since the amoeba is always surrounded by water and there is no water-proof skin around it, water is always collecting inside the protoplasm. The excess water along with some other waste products are excreted by the contractile vacuole. The contractile vacuole fills with water, enlarges into a sphere and suddenly bursts throwing out the water. This process repeats at regular intervals of time. Waste material is also expelled through the ectoplasm from the general body surface.

SENSITIVITY

An amoeba shows definite response to an external stimulus. It tries to move

away from bright light to regions of moderate light. From hot or cold region, it tries to move away towards regions of moderate temperature. The pseudopodia can make out a food particle from a grain of sand or other non-food material.

If a weak electric current is passed through water containing amoeba, it withdraws its pseudopodia and becomes round. When put in a weak solution of acid or alkali, an amoeba tries to get away.

GROWTH AND REPRODUCTION

An amoeba gradually grows in size and every few days stops feeding and becomes spherical; then its nucleus elongates (diagram 102 *a*). The nucleus then divides into two halves while the protoplasm also divides into two parts, each part containing one section of the nucleus (diagram 102 *b*). This process is called ***binary fission***. Each of the parts is a complete living amoeba and grows into a bigger size under favourable conditions (diagram 102 *c*). The adult amoeba then divides again reproducing further off-spring. The process thus goes on; thus, an amoeba never dies a natural death.

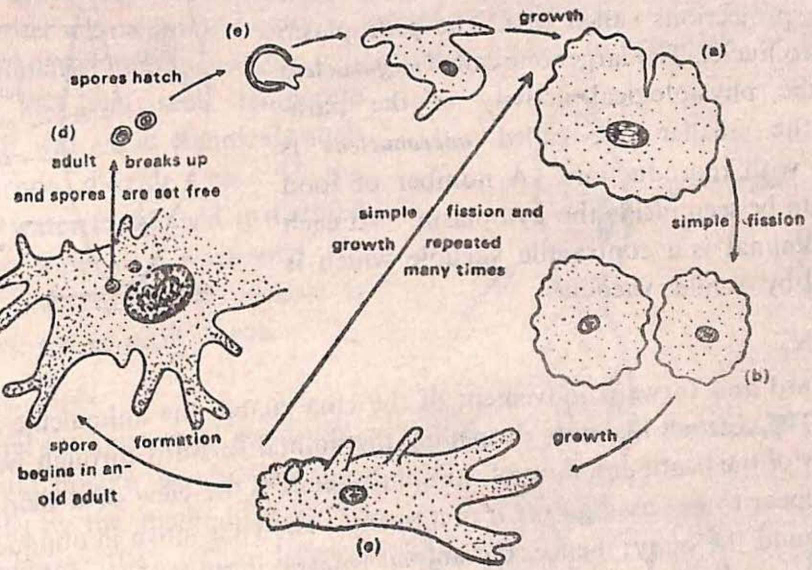


Diagram 102

Under unfavourable conditions such as in a dry pond, the amoeba sometimes secretes a protective wall of dead material round it. In this resting stage it can remain passive for some time until favourable conditions are obtained. In this dormant stage, the amoeba nucleus sometimes divides into a number of nuclei round each of which gathers a little protoplasm; these small bits of cells are called *spores*. Thus, when an adult breaks up and the spores are set free, this process is called ***multiple fission*** (diagram 102 *d*). The spherical spore may be as small as 5μm (5×10^{-6}m) in diameter. It can be easily blown about by wind. Under favourable conditions on

the return of the spore to water, the outer covering breaks, the amoeba hatch out and feed actively (diagram 102 *e*).

Thus, an amoeba is a simple unicellular animal which has all the characteristics of any other living organism.

PARAMECIUM

Paramecium, like an amoeba, is a single cell animal found in muddy pools. It has, however, a definite shape from which it derives the name 'slipper animalcule'. The structure of paramecium is more complex than an amoeba.

The end that leads during locomotion, ***anterior end***, is more rounded than the ***posterior*** end. On the ***ventral*** side there is a shallow groove which leads into a depression called the ***gullet*** (diagram 103). The mouth is situated at the base of the gullet. The cytoplasm has a distinct outer layer called the ectoplasm, and the inner endoplasm. The ectoplasm is covered by a thin membrane with a number of thread-like projections called ***cilia***. The protoplasm contains two nuclei. The larger one called ***meganucleus*** controls the physiological activity of the paramecium; the smaller one called ***micronucleus*** is concerned with reproduction. A number of food vacuoles can be seen inside the cytoplasm. At each end of the animal is a contractile vacuole which is surrounded by smaller vacuoles.

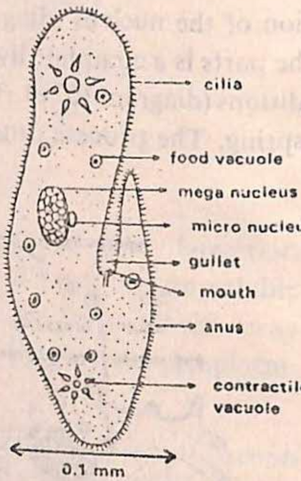


Diagram 103

MOVEMENT

The backward and forward movement of the cilia enable the animalcule to move forward. The cilia act like oars propelling the animal forward through water. A surface view of the beating motion of the cilia resembles the view of a field of corn as waves appear to be passing over it in a breeze. The cilia move in oblique waves, spirally around the body; hence, the animal rotates about its long axis during its movement in water.

FEEDING

By the lashing movement of the cilia, food particles in the water are directed towards the mouth through the oral groove. Small unicellular plants and animals are used as food for the paramecium. The food particle and a drop of water are drawn inwards and finally enclosed to form a food vacuole. By the streaming movement of the endoplasm, the food vacuoles take a course round the body as digestion takes place. The undigested particles are expelled out from a small aperture, called the anus, which is situated close to the gullet.

RESPIRATION

The respiratory function of a paramecium is similar to that of an amoeba. Oxygen is taken in through the general body surface, and carbon dioxide is given out also from the surface, by the process of diffusion. Carbon dioxide is also given out from the contractile vacuoles.

EXCRETION

Excess water entering the body of the animal and dissolved waste matter gather in the small vacuoles surrounding the contractile vacuoles at each end of the animal. The smaller vacuoles then empty out into the larger one, which becomes bigger and finally contracts to expel the water and waste. This process is regularly repeated.

SENSITIVITY

Paramecium move largely in response to external stimuli. When a paramecium comes in contact with a foreign body, it moves away from it. This is its avoiding reaction. Similarly, the animalcule will avoid a region of too high or too low temperature and will seek temperate conditions. It will avoid chemicals such as acids, carbon dioxide, etc. If the surrounding water is changed to distilled water, glucose-water or a weak acid, the working of the contractile vacuole is seen to speed up or slow down.

REPRODUCTION

Under normal environmental conditions, a paramecium breaks up to form two daughter cells by the method of binary fission (diagram 104). The different stages show that the micro and the mega-nucleus become elongated and dumb bell shaped; the cytosplasm is constricted transversely and then the division takes place. One of the part possesses the gullet while the other develops a new one. Each part has a contractile vacuole and each of the two nuclei. The whole process of division and development takes about two hours. After another ten hours, the newly formed paramecia can begin further reproduction. This method of reproduction is called ***asexual reproduction.***

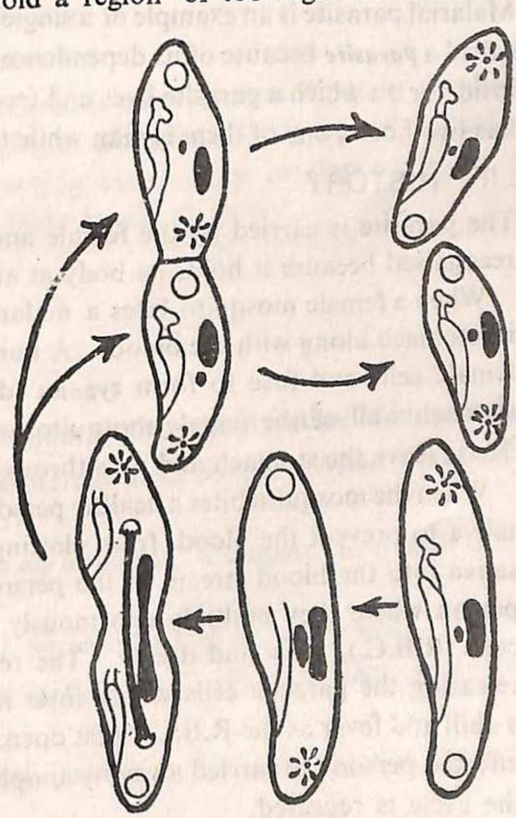


Diagram 104

When paramecia are multiplied by several binary fission, they begin to show a deterioration in their function and structure. At this stage the process of ***conjugation*** takes place. ***Conjugation is a process when two of the living organisms come together in physical contact and the transfer of nuclear material takes place.***

In paramecium, the process of conjugation acts as a stimulant and gives renewed vigour to the pair. The two animalcules come in contact at their ventral surfaces and their protoplasm becomes continuous across a narrow bridge. The meganucleus disappears and the micronucleus divides to form a big female and a small male nucleus. The male nucleus crosses over to the other paramecium and fuses with the female nucleus. The two paramecia now separate and start further division. This method of reproduction is called ***sexual reproduction.***

While paramecium is a single-celled living organism like the amoeba, it shows a structure and function of greater complexity. While the characteristics of living are the same, the processes by which these are exhibited are not identical.

MALARIAL PARASITE

Malarial parasite is an example of a single-celled animal which is not free living. It is called a ***parasite*** because of its dependence on other living organisms. The organism inside or on which a parasite lives and feeds is called the ***host***. The malarial parasite has two hosts; one of them is man while the second is the ***anopheles mosquito***.

LIFE HISTORY

The parasite is carried by the female anopheles mosquito. This mosquito can be recognised because it holds its body at an angle to the surface on which it rests.

When a female mosquito bites a malaria patient, some of the parasites pass into its stomach along with the blood. A number of these parasites behave as male and female cells and fuse to form ***zygotes*** (diagram 105). The zygotes penetrate the stomach wall of the female mosquito and multiply to form spindle-shaped cells. These leave the stomach and pass through body fluids to the salivary glands.

When the mosquito bites a healthy person to suck in blood, it passes out some of the saliva to prevent the blood from clotting. Some parasite cells pass out with the saliva into the blood stream of the person. They first penetrate the liver of the person where they multiply enormously. The parasites then enter the red blood cells (R.B.C.), grow and divide. The red blood cells so affected then burst open releasing the parasite cells which enter more blood cells. The person experiences a chill and fever as the R.B.C. burst open. The parasites from the blood of such an affected person are carried away by anopheles mosquito which bites the person; thus the cycle is repeated.

At one time some years ago malaria was widespread in most tropical countries. Control measures are now being taken on national scale and although it was largely

eradicated from India, there are some indications of its resurgence. From the life history of malarial parasite, it is obvious that the disease cannot spread in the absence

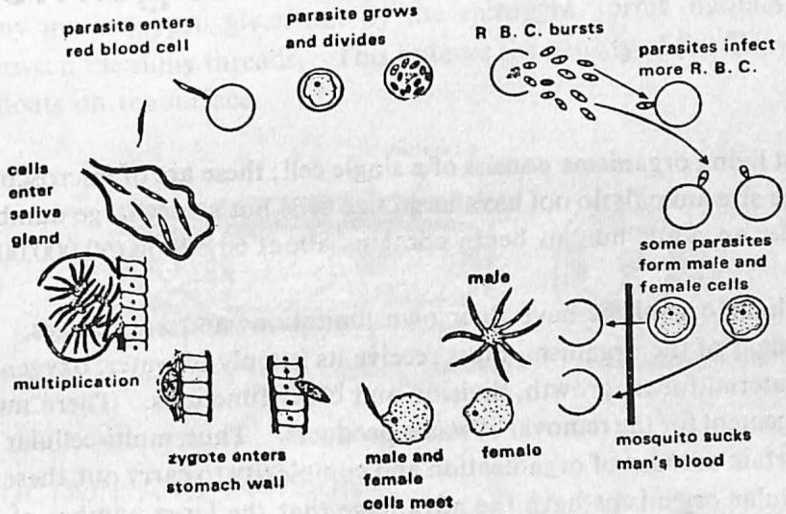


Diagram 105

of the mosquito. The eradication of mosquitoes can therefore wipe out the disease. The life history of mosquito is similar to that of a house fly; it passes through the larva and pupa stages. Mosquito breeding takes place in stagnant water and they can be destroyed by the spraying of DDT or oil.

PROBLEMS

1. With the help of a clear, labelled diagram explain the structure of an amoeba.
2. What is the food of an amoeba found in fresh water ponds? What is the function of contractile vacuole in an amoeba?
3. Name the organs of locomotion in an amoeba? Compare them with those of paramecium.
4. Compare the feeding mechanism in an amoeba and a paramecium.
5. What are the characteristics of a living organism? How do these apply to the paramecium?
6. Trace the life history of the malarial parasite. At what stage can the parasite population be controlled?
7. What is meant by a parasite? What is meant by a host in relation to a parasite? Why is study of the life history of organisms important to us?

14 Multicellular Organisms

The simplest living organisms consist of a single cell; these are of microscopic dimensions. Large size animals do not have large size cells but a very large number of cells. For example, an adult human being contains about 60 billion (60,000,000,000,000) cells.

Multi-cellular organisms have their own limitations and advantages. Each cell, as a component of the organism, must receive its supply of water, oxygen and other chemical material for its growth, division and other functions. There must also be some arrangement for the removal of waste products. Thus, multi-cellular organisms possess a certain amount of organization and complexity to carry out these functions.

Multi-cellular organisms have the advantage that the large number of cells work in cooperation and increase the efficiency of its working. The cells are not usually alike; they vary according to specialised functions. A complex organism has a large number of tissues and organs made up of many different types of cells which function according to the needs of the whole organism.

In unicellular organisms, the cell usually multiplies by the process of binary fission. The cells in multicellular organisms are also produced by division but usually remain attached together to form the body of the organism. We shall study two of the simplest multicellular organisms, a plant and an animal.

SPIROGYRA

The spirogyra is a simple green plant which grows commonly in stagnant water and slow-moving streams. The usual habitat of this organism is just below the water surface; its density is almost equal to that of water.

STRUCTURE AND FUNCTION

The plant measures about 8 to 16 cm in length and appears like a green thread. Usually many of these cylindrical threads are found entangled. Each plant is unbranched having a number of cells arranged in a single row; the cells are all alike.

Each cell of this filament-type plant has a wall made up of cellulose and ***mucilage***. The mucilage helps protect the filament against ***predators*** which live on it. The cytoplasm has large vacuoles in it and a number of spirally-coiled chloroplasts. The nucleus is suspended by strands inside the cytoplasm (diagram 106).

The chloroplasts are ribbon-shaped (diagram 106); their position is directly below

the cell wall. Their spiral shape and position provide a large surface for absorbing sunlight for photo-synthesis. The process of photo-synthesis quickens on sunny days; this results in a high output of oxygen which soon saturates the surrounding water. Any more oxygen given out by the spirogyra forms bubbles which get trapped between the slimy threads. This reduces the density of the filament and the organism floats on the surface.

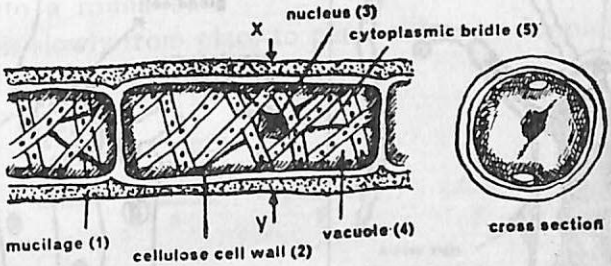


Diagram 106

REPRODUCTION AND DIVISION

Spirogyra reproduce by sexual conjugation. Normally two spirogyra come together and lie parallel to each other as if two ladders placed close together. The cell walls at the points of contact disintegrate and the protoplasmic material from one cell is transferred into the other adjoining it. When they fuse together, they form the zygote.

The zygote gets covered with a protective shell, and is then called the zygospore *z* (diagram 107). Cells *x* in the other filament remain empty. In due course of time, when external conditions are favourable, the outer wall of the zygospore bursts open and releases a small filament. The cells of this filament further divide to form a full-grown spirogyra. Thus, in spirogyra all cells can divide to increase the length of the filament. The filament can also fragment to produce a number of individual organisms.

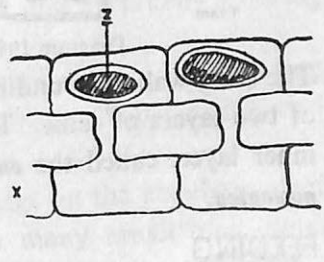


Diagram 107

HYDRA

The hydra is a common multicellular animal which has a simple organization. It lives in ponds and lakes, especially during the spring and summer. It is shaped like a hollow cylinder. When extended it can reach a length of almost 2 cm; when contracted it becomes a small globular organism.

STRUCTURE

At one end it has a flat adhesive disc with which it can attach itself to the surface film

of water, to leaves or stones, or to any other solid object. From the other end projects a conical structure which has a mouth at its apex (diagram 108). Around the base of this cone are six, seven or eight hollow ***tentacles*** which are used for catching small water insects.

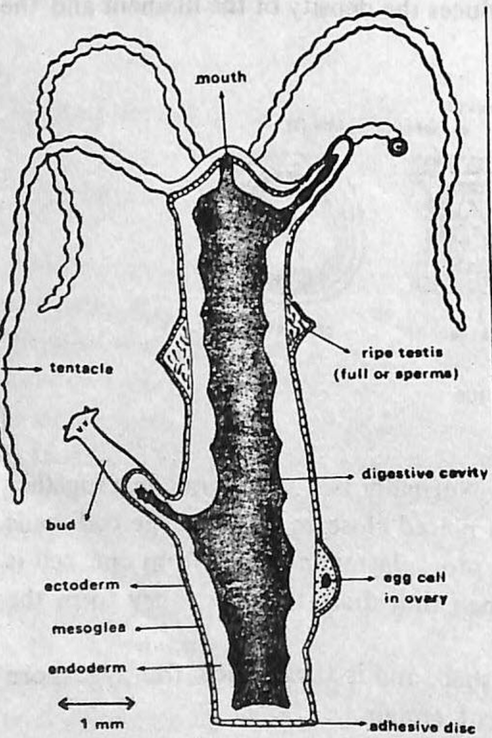
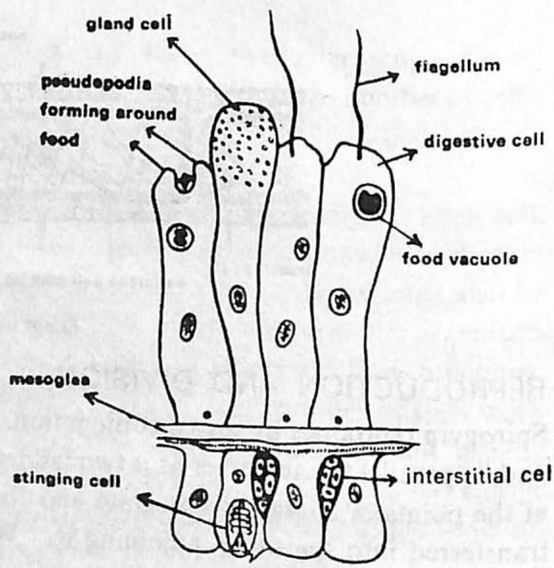


Diagram 108



Structure of body wall of Hydra

Diagram 109

The body wall surrounding the middle cavity, called the ***digestive cavity,*** is made up of two layers of cells. The outer layer called the ***ectoderm***, is separated from the inner layer, called the ***endoderm,*** by a thin layer of jelly like material called the ***mesoglea.***

FEEDING

Hydra feeds on water fleas as well as other water insects. It catches its prey with the help of special ***stinging cells*** present on the tentacles. Once the prey is stunned, other tentacles curl around it and draw it towards the mouth through which it enters the digestive cavity.

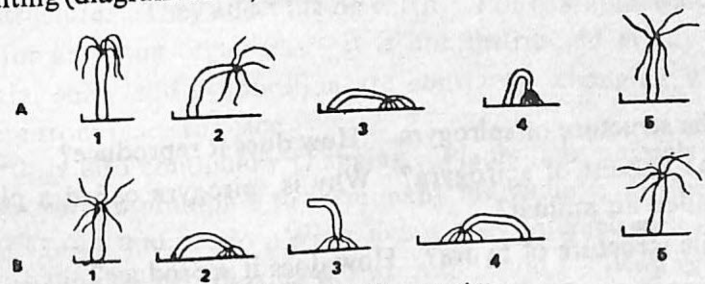
Once the prey is inside the digestive cavity, ***gland cells*** in the endosperm pour out digestive juices which help to break it up into small fragments. Digestion is then completed by ***digestive cells*** which engulf fragments at their inner ends forming food vacuoles similar to those in an amoeba. Pieces of undigested matter are passed out through the mouth.

The hydra does not have any special cells or structures to carry out the process of respiration and excretion. Oxygen, carbon dioxide and excretary material diffuse in and out through the general body surface.

LOCOMOTION AND MOVEMENT

Hydra remains attached to one place for a long period but continuously moves its body and tentacles. When its tentacle is touched by an external object, the whole body contracts into a round ball.

The hydra moves slowly from place to place either by looping (diagram 110 *a*) or by somersaulting (diagram 110 *b*).



Hydra showing locomotion
Diagram 110

REPRODUCTION

The hydra reproduce by both sexual and asexual methods.

(a) Asexual reproduction. Bulges or buds develop on the body of a well fed hydra. The buds gradually grow and develop tentacles, and finally a mouth forms at the free end of the buds. The buds then narrow down at the base and eventually a young hydra frees itself to lead an independent existence.

(b) Sexual reproduction. Most of the hydra are hermaphrodites, each having male and female sex parts which mature at different times. Thus, hydra also reproduce sexually although self fertilization is not possible.

At the beginning of winter, a hydra forms many swellings on the ectoderm near the mouth; these are called ***testes.*** The testes contain many small unicellular bodies called the ***spermatozoa.*** The spermatozoa has a whip like tail with which it can swim around. When the testes ripen, they burst open releasing the spermatozoa. The released male cells swim around in the water.

Later, a hydra develops another swelling on the ectoderm nearer its base; this is called the ***ovàry.*** One of the cells in the ovary becomes very large; this is called the ***ovum.*** Some of the sperms swimming in the water find their way to the ovary and one of them fertilizes the ova which remains exposed in the ovary. When the male cell fuses with the female cell, they form the zygote.

The zygote now divides repeatedly to form the ***embryo.*** The embryo secretes a

cyst around itself before it drops off the parent onto the mud. Here it may lie dormant for several months, protected by the cyst, until around spring a young hydra emerges from it. The young hydra starts to feed, grow and reproduce by budding.

If a hydra is cut into an upper and a lower part, each part will grow the missing region and become a complete hydra. This process is called ***regeneration***.

Although a very tiny animal, the hydra shows a great deal of complexity of structure as compared to the protozoa. There are different regions of its body and different kinds of cells. Each type of cell has its own task to perform.

PROBLEMS

1. Describe the structure of spirogyra. How does it reproduce?
2. What is the habitat of spirogyra? Why is spirogyra called a plant while the hydra is called an animal?
3. Describe the structure of hydra? How does it reproduce?
4. What is regeneration? Give an example of regeneration in animal and plant.

15 Photosynthesis and the Ecological Balance

A number of physical factors in nature are constantly changing. Some of these factors are air, water content in soil and atmosphere, temperature, light from the sun and soil structure. They affect life on earth. For example, water is an essential requirement for all living organisms. It is not distributed evenly over the earth. Moreover, rain, snow and evaporation are constantly changing water content in the atmosphere from place to place.

Life on earth is also continually changing. Plants and animals begin life from a cell which grows and multiplies to form many individuals; in due course of time they wither away, die and decay. While living, they interact with the air, inhaling oxygen and exhaling carbon dioxide during respiration. Living organisms obtain food from the surroundings and give out waste material. Thus, living organisms are continually affecting and altering the environment. The study of interaction between the environment and the living organisms is called ecology.

PRODUCERS AND CONSUMERS

All living organisms, whether the simple forms of life such as an amoeba and paramecium or the more complex types like the mammals and trees, have to struggle for their existence. The animals depend on the plants, directly or indirectly, for their supply of food. Animals are therefore called the ***consumers.***

Organisms, mostly green plants, which contain the structures called chloroplasts in their cells are unique in the world because they can manufacture food taking energy and material from the non-living world. They are therefore called the ***producers.*** All animals, the consumers, depend upon the plants, and can have no independent existence. While animals have to compete against one another for their supply of food, plants also have to strive for sun light, water and necessary chemicals from the soil. Thus a biological change is always going on in nature.

THE BIOSPHERE

The thin shell at the surface of the earth within which all living beings are found is called the ***biosphere.*** The biosphere extends to the limits of light penetration in the sea and to the limits of root penetration on land. It extends upwards into the lower levels of the atmosphere. Although life on earth and physical factors are continually changing on the earth, there is good reason to believe that the total balance of the life

system has not appreciably changed over thousands of years. Nothing is being added to or removed from the total supply of materials, which are only changing physical and chemical forms.

The only external factor into this biosphere is the radiant energy from the sun. This radiant energy, mainly in the form of infra red and light, is the source of all physical and biological changes going on in the biosphere. In order to appreciate this fact, we shall study the process of photosynthesis in more detail.

PHOTOSYNTHESIS

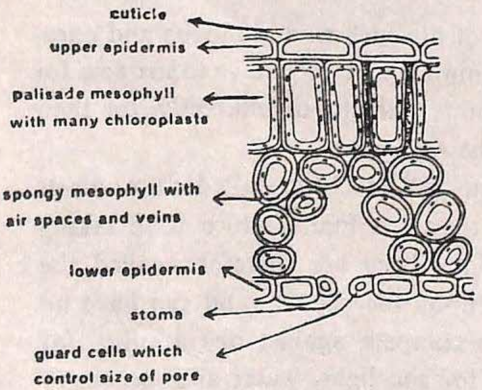
The manufacture of glucose with the release of oxygen utilising solar energy and materials from the non-living world is the function of leaves, and the process is called photosynthesis. The chemical reaction can be written as follows:

$$\textit{carbon dioxide} + \textit{water} \xrightarrow[\textit{using sun light}]{\textit{by chlorophyll}} \textit{glucose} + \textit{oxygen}$$

In simple words the energy from the sun is locked up as chemical energy in the glucose. Chlorophyll, which is responsible for the process of photosynthesis, is present in structures called chloroplasts inside some of the leaf cells.

STRUCTURE OF A LEAF

If a thin transverse section of a leaf is viewed under a microscope, it shows the internal structure made up of several tissues. The inside cells are packed between two layers of cells called the ***epidermis*** (diagram 111); both layers are transparent and do not contain chloroplasts. The ***upper epidermis*** secretes a waxy layer called the ***cuticle*** on the top surface; this prevents the evaporation of water through the surface.



Transverse section of a leaf
Diagram 111

In between the epidermis are the ***mesophyll*** cells which contain the chloroplasts. The mesophyll is made up of two layers, the ***palisade layer*** above and the ***spongy layer*** below. The palisade is a layer or two of closely packed cells; the cells are long and arranged breadthwise. Each cell contains about 50 chloroplasts.

The spongy layer is loosely packed with lots of air spaces in between. These cells contain relatively a few chloroplasts. The cells are irregular in shape. In between the mesophyll lie the conducting paths for water and food material which form the veins in a leaf. These contain the ***xylem*** and the ***phloem*** cells protected by

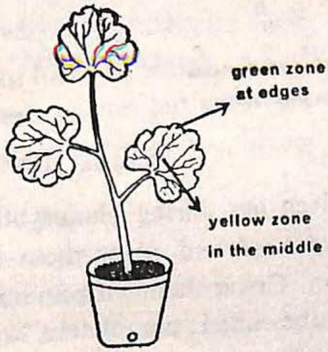
sheath cells. The xylem cells carry water and dissolved salts, from the roots to other cells of the leaf. The phloem carry the food, made by mesophyll cells, away to other parts of the plant for use and storage.

The lowest layer of a leaf is the lower epidermis. It looks very similar to the upper epidermis except that the surface has a number of openings called the ***stomata*** (plural of ***stoma***). A stoma is surrounded by two ***guard cells*** which control the size of the opening. Carbon dioxide enters a leaf through the stoma. (In water plants, however, carbon dioxide in solution enters a leaf through the whole surface from the surrounding water.)

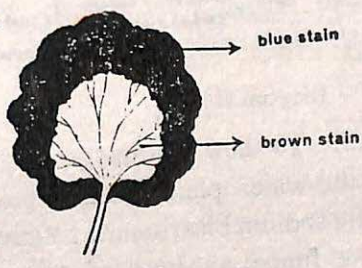
The carbon dioxide which enters a leaf diffuses through the air passages in a leaf and finally enters the chloroplasts in cells. The gas gets used up as fast as it enters and some more carbon dioxide is drawn in. Oxygen, which is a byproduct of photosynthesis, comes out of the leaf through the stomata.

A number of simple classroom experiments can be performed to investigate the part light energy, chlorophyll, carbon dioxide and oxygen play in the process of photosynthesis.

Activity 1. To show that chlorophyll is essential for photosynthesis. Choose a geranium plant whose leaves have patches of white and green. A plant having such patches is called ***variegated.*** Carry out the ***starch test*** early in the morning on one or two leaves of this plant as follows.



(a) Potted geranium plant



(b) Starch test on leaf after after exposure of a variegated leaf to sun light

Diagram 112

Dip the leaves in boiling water for a few seconds. Now place them in methylated spirit in a shallow dish and warm indirectly over a water bath. (A beaker half filled with water placed on a heat source is convenient.) The green matter in the leaves is removed and they become pale. Now remove the leaves, wash them in water and spread them flat on a glass plate. Cover them with iodine solution and allow to stand for some time. Wash away excess iodine when the part of the leaf

containing starch will be stained blue black. This test shows the presence of starch in the leaf.

When tested early in the morning the leaves show that starch is absent from both the green and white parts. Now leave the plant in sun light for about 5 hours and then test one or two leaves for starch. The leaves show the presence of starch only in the portion which was green, and therefore contained chlorophyll (diagram 112 *b*).

Activity 2. To show that carbon dioxide is essential for photosynthesis. Choose a geranium plant early in the morning so that its leaves are free from starch. Enclose one of the leaves in a conical flask containing caustic soda solution (diagram 113). Caustic soda solution is an absorbant of carbon dioxide.

Keep the potted geranium in sun light for a few hours and carry out the starch test on the leaf inside the flask and a leaf outside the flask. You will observe that the leaf from inside the flask stains brown with iodine while the one from outside stains blue (diagram 114). Thus, starch was not formed in the leaf inside the flask due to the absence of carbon dioxide.

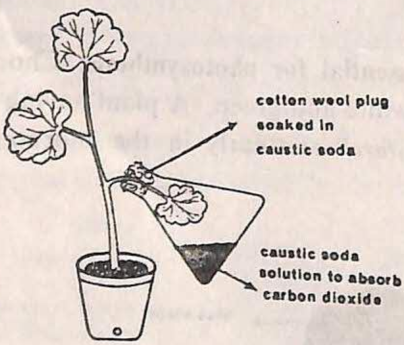


Diagram 113

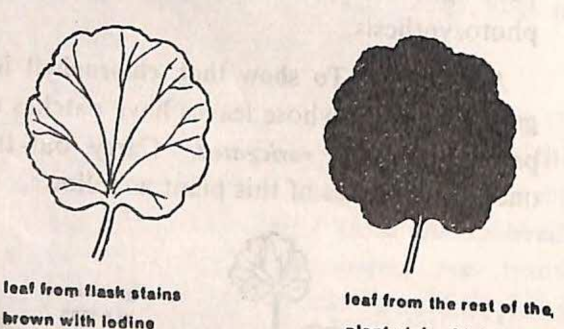
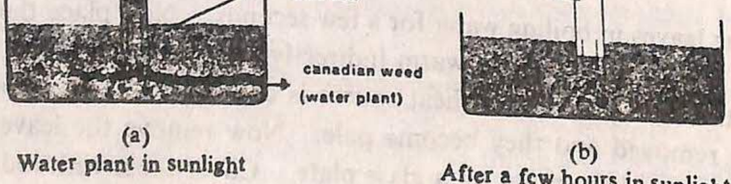


Diagram 114

Activity 3. To show that oxygen is given out during photosynthesis. Cut a few lengths of the water plant ***canadian pond weed*** and place them in a trough containing dilute sodium bicarbonate solution. Cover them with an inverted funnel, and place on the funnel an inverted test tube filled completely with the solution (diagram 115 *a*).



(a)
Water plant in sunlight

(b)
After a few hours in sunlight

Diagram 115

Place the apparatus in sun light for a few hours. It will be observed that the solution is displaced by a gas (diagram 115 *b*). When tested with a glowing splint, the gas is seen to support combustion. The gas is oxygen. Experiment to show the necessity of sunlight during photosynthesis has been explained in Introductory Science—Book 1.

IMPORTANCE OF PHOTOSYNTHESIS

(*a*) Green plants are the only things known to produce glucose by the use of water and carbon dioxide. The glucose sometimes changes to another form of sugar ***sucrose*** which we commonly use in our food.

(*b*) In most plants the glucose quickly changes into starch. Any excess sugar and starch not needed by the plant is stored in other parts of a plant. Sweet potato, beet and turnips store food in their roots. Rice and barley store food in their seed grains mainly in the form of starch.

(*c*) The glucose in some plants is converted into oils and fats and stored in various parts. These are used by us as a cooking medium and for other purposes. Examples of such stored material are castor oil, coconut and groundnut oils, which are stored in the seeds.

(*d*) A plant gains various minerals such as sulphur, nitrogen and phosphorus as dissolved salts in water through the roots from the soil. These minerals combine with the glucose to form complex cellulose and protein molecules. Protein is the building matter of protoplasm. Cereals of various types contain a lot of protein.

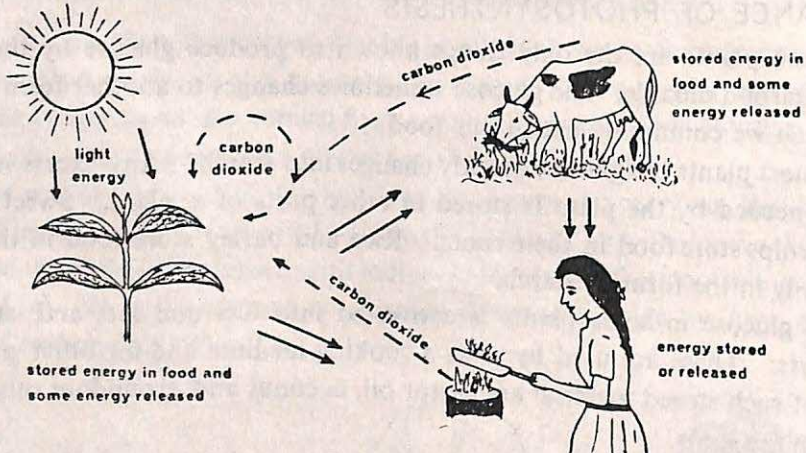
Besides the plant which manufacture food, all animals depend on them for their supply of food in the form of starch, oils, fats, proteins and sugar. In addition, photosynthesis in plants carries out an essential function in maintaining a balance of carbon dioxide and oxygen in the biosphere.

THE CARBON CYCLE

All living matter contain carbon. As plants and animals grow and multiply they require more and more carbon which is in chemical combination in starch, sugar, proteins and oils. This carbon primarily comes from the atmospheric carbon dioxide during photosynthesis in green plants. Free carbon dioxide forms 0.03 per cent by volume of atmospheric air.

The carbon present in living organisms escapes to the atmosphere during respiration. Burning of oil, coal and wood also release large quantities of carbon to the atmosphere in the form of carbon dioxide. Thus a circulation of carbon goes on continually; this is called the ***carbon cycle*** (diagram 116). The rate of circulation and its distribution alters from place to place depending upon vegetation and other physical factors, but the total content is constant. It will continue to remain unchanged unless animal and plant life are drastically altered.

Like carbon, oxygen also undergoes a cycle of change. Oxygen is essential for combustion and respiration. In both these processes, the oxygen combines with carbon. This oxygen is taken from the atmosphere. The total content of oxygen in the atmosphere however remains constant in the biosphere due to release of oxygen during photosynthesis.



The carbon cycle

Diagram 116

THE NITROGEN CYCLE

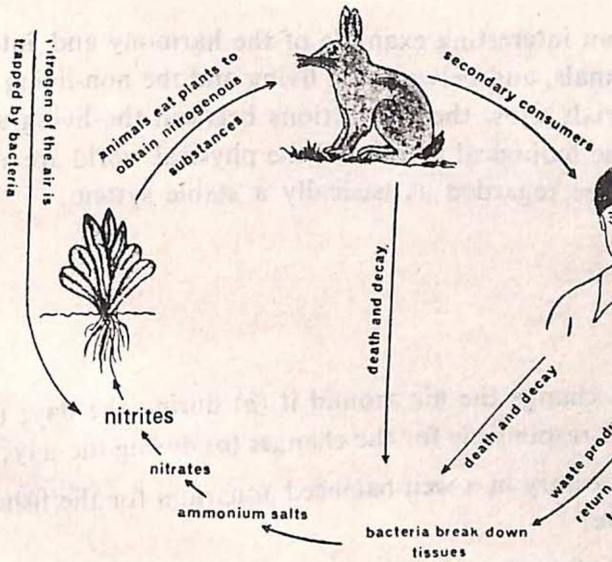
Nitrogen, like carbon dioxide, exists freely in the atmosphere and in abundant quantity. This nitrogen is however mostly unavailable to living organisms directly. There are certain types of bacteria and algae which take the atmospheric nitrogen directly and convert them into nitrates using chemicals in the soil. Roots of some plants called *legumes*, such as garden peas and pulses, have some types of these *nitrogen-fixing bacteria.* The nitrates from the soil dissolved in soil water are taken up by plants.

All other animals obtain their supply of nitrogen from the plants. Nitrogen is present in all proteins and nucleic acids. It is therefore an essential constituent of all living organisms. This nitrogen content necessary to animals comes from plants and other small animals through food supply. When plants and animals die and decay, the nitrogen returns to the soil and by the action of certain bacteria is converted into nitrates; it is then used up by plants through soil water and thus re-cycled (diagram 117).

Similar cycles exist for the other elements which are of importance to living organisms, such as calcium, potassium, sodium, sulphur and phosphorus.

THE ENERGY SOURCE

The constant circulation of materials through living organisms requires a source of



The nitrogen cycle
Diagram 117

energy. Energy has, in the long run, to flow into the biosphere. The ultimate source of energy is the sun. Of the total light energy that falls on the exposed surfaces of plants, some is lost by reflection. Another part is used up for evaporation of water from leaves; this process is called ***transpiration.*** What is effectively absorbed is called the ***energy value*** of the plant tissues which is built up by photosynthesis. This is about 2 per cent of the light energy, or 1 per cent of the total energy reaching the earth. Thus, photosynthesis is a process of conversion of light energy into chemical energy which goes on in green plants.

The chloroplasts in mesophyll cells are disc shaped elongated structures. It has been observed that they orient themselves (change their position within the cells) during strong sun light and weak sun light to receive the necessary amount of light (diagram 118).

As plants are eaten, the energy value they represent is transferred to the next level, the first consumer, in the food chain. At each step of transfer there is an energy loss. For example, ten tonnes of grass per year may yield growth of only one tonne of cattle per year. This energy loss is utilised in maintenance of body temperature in warm blooded animals, movements, repair of tissues, excretion, undi-gested material etc.

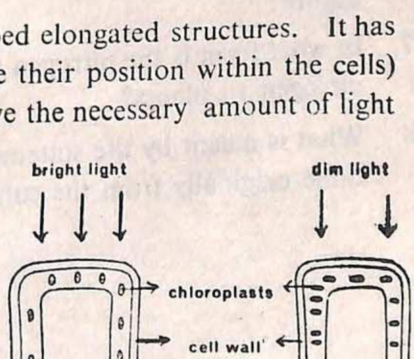


Diagram 118

Biology provides us an interesting example of the harmony and interdependence between plants and animals, and between the living and the non-living world. The cycles of various materials show the interactions between the living world and its surrounding. While the biological world and the physical world are always changing, the biosphere can be regarded as basically a stable system.

PROBLEMS

1. How does a plant change the air around it (*a*) during the day; (*b*) at night? Explain the process responsible for the changes (*a*) during the day; (*b*) at night.
2. Why are plants necessary in a well balanced aquarium for the fishes and other animals to survive?
3. What is the source of energy released by burning sugar or starch in a test tube? Where do similar processes take place in living organisms?
4. A 17th century scientist carried out an experiment on the growth of plants and concluded that "about 75 kg of wood, bark and root had arisen from the water alone". Give reasons why the conclusion is not correct.
5. Why is the manufacture of food by green plants called "photosynthesis"? Explain the function of various cells in a leaf in this process.
6. Name two examples besides respiration which are responsible for increasing the carbon dioxide content of the air. How is a balance of carbon achieved in nature?
7. In what form is the nitrogen absorbed by most plants? What is the use of this nitrogen to plants?
8. What is meant by the statement "the energy used by you to pick up this book came originally from the sun?"

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